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INVESTIGATION OF TEXTILE DYEBATH RECONSTITUTION AND REUSE

Volume 2. Operations Manual

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16. ABSTRACT The two-volume report gives results of a detailed examination of dyebath reconstitution and reuse, one of several wastewater recycle/reuse technologies allowing textile finishing mills to reduce the volume of wastewater and the amount of pollutants discharged. (NOTE: About 80% of these plants discharge their wastewater to publicly owned treatment works (POTWs). Most of the wastewater receives little or no pretreatment before discharge into municipal collection systems.) This recycle technology is considered promising for several reasons: significant environmental benefits, potential for widespread application, low capital cost, cost savings in textile dyeing, and economic attractiveness. Volume 1 gives results of the investigation at a carpet mill. It gives results of bench-, pilot-, and full-scale testing, presenting wastewater data documenting the achieved pollutant reductions. It addresses the economic feasibility of implementing the technology full-scale. Volume 2 gives detailed procedures and methods for implementing the technology, serving as an operations manual for other mills wishing to investigate the technology.

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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Textile Finishing	Stationary Sources	13H
Dyeing	Dyebaths	
Water Treatment	Reconstitution and Reuse	
Waste Water	Carpet Mills	

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ABSTRACT

Approximately 80 percent of textile finishing mills discharge their wastewater to publicly owned treatment works. The majority of the wastewater receives little or no pretreatment before discharge into municipal collection systems. A variety of wastewater recycle/reuse technologies allowing these mills to reduce the volume of wastewater and the amount of pollutants discharged were described in the report covering Phases I and II of this project.

This report, covering Phase III of the project, examines one of these recycle technologies, dyebath reconstitution and reuse, in detail. This recycle technology is considered promising for a number of reasons including its significant environmental benefits, potential for widespread application, low capital cost, cost savings in textile dyeing, and economic attractiveness.

Volume 1 of this report presents the results of a detailed investigation of dyebath reconstitution and reuse at a carpet mill. The results of bench-, pilot-, and full-scale testing are presented. Wastewater data documenting the pollutant reductions achieved through dyebath reuse are presented. The economic feasibility of implementing the technology full-scale is addressed.

Volume 2 of this report presents detailed procedures and methods for implementing dyebath reconstitution and reuse. Its purpose is to serve as an operations manual for other mills wishing to investigate this recycle technology.

This report is submitted in accordance with Contract Number 68-02-3678 between the U.S. Environmental Protection Agency and Sverdrup & Parcel and Associates, Inc. It documents the work performed under Phase III of the contract.

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SECTION I
INTRODUCTION

Dyebath reuse by reconstitution is a relatively inexpensive approach to energy and material conservation. Simply stated, this approach consists of (1) saving an exhausted dyebath, (2) analyzing it for remaining dye amounts, (3) adding make-up quantities of dyes and chemicals, and (4) reusing the bath for another dyeing. However, unlike many recycle technologies, it is not an "off-the-shelf" item that can be purchased from a supplier and quickly installed. Rather, it is more akin to a dyeing process modification, and thus the involvement of textile mill personnel is important to its implementation and success. Unfortunately, only limited information has been available to assist the textile producer in determining how, or even whether, to pursue implementation of dyebath reuse by reconstitution at his mill.

These conditions have resulted in an apparent paradox: a very economically attractive (over 30 percent annual rate of return), widely applicable technology that has been virtually neglected by most of this country's textile industry. By the very nature of dyebath reconstitution/reuse, there is no identifiable product for a supplier to manufacture and his vendor to sell. And yet to the textile mill owner, plant manager, dyehouse superintendent, and other mill personnel (those with whom the impetus for instituting dyebath reuse must begin), the limited information has undoubtedly seemed esoteric or insufficient, and the technology irrelevant or even unproven. This manual will attempt to remove some of these latter impediments by showing that dyebath reconstitution has unquestionably been proven, both economically and technically, and by presenting a complete and easily used guide to this dyebath reuse technology.

BACKGROUND AND PURPOSE

This implementation manual is Volume 2 of a report on dyebath reconstitution and reuse developed under Phase III of EPA Contract 68-02-3678, an Evaluation of the Potential for Wastewater Recycle and Reuse in Indirect Discharge Textile Mills.

Volume 1 describes the activities performed under this project relative to dyebath reuse implementation at a selected carpet mill. It reviews the background for this report and examines the experimentation/implementation process at this carpet mill. As with most of the previous literature on the subject of dyebath reuse by reconstitution, the principal purpose in Volume 1 is to publish research experiences and results.

In contrast to Volume 1 and previous reports, the objective in Volume 2 is to present in a logical sequence the information needed by textile mill personnel to confidently evaluate and implement dyebath reuse at their own dyehouse operations. Hopefully, the information contained in this "handbook" will clarify the concepts associated with reconstitution and provide sufficient guidance to assist in the establishment of dyebath reuse systems at numerous mills in the textile industry.

FORMAT

This implementation guide is organized as follows:

Section II provides an introduction to the principal features of dyebath reuse by reconstitution. The benefits associated with reconstitution are noted.

Section III is intended to allow readers to determine whether reconstitution will likely be feasible at their mill. Reconstitution is not applicable to all dyehouses. The information presented in this section provides a basis for enabling mill personnel to decide whether this reuse technology is tailor-made, conditionally applicable, or inappropriate for their dyehouse operation.

For those dyehouses with potential, Section IV describes the elements of an evaluation program to assess the technical feasibility of dyebath reuse at these mills. The various considerations that must be weighed in developing an evaluation program are explored.

Section V presents the theoretical aspects, principles, and procedures of performing absorbance measurements needed for dyebath analysis. While the material coverage is similar to that presented in

Volume 1, the discussion here is more comprehensive. The information in Section V complements and provides an important foundation for the discussions that follow in Section VI.

Section VI shows how exhausted dyebaths are analyzed to determine residual dye concentrations. A few "one-time only" activities are required to develop data on individual dyestuff characteristics prior to dyebath analyses, and these are explained in an easily-followed progression. The use of this data in conjunction with exhausted dyebath measurements to determine residual dyestuff amounts and make-up quantities is illustrated.

Section VII shows how a desktop computer can be used to perform most of the manpower tasks and calculations necessary for dyebath analysis. Programs are available that require no computer programming experience. These are presented to illustrate how simply dyebath reuse is achieved with the help of these units.

Section VIII describes the performance and assessment of dyebath reconstitution experiments conducted in the laboratory or with a small-scale dye unit at a mill. These bench- and/or pilot-scale dyeings are used to develop information quickly and easily and to prepare for full-scale experiments.

The features of full-scale trials are described in Section IX. Particular emphasis is placed on preparations that are necessary to facilitate the performance of these reuse trials.

Section X presents information to assist in the transition from the experimental phases of dyebath reconstitution to its use in day-to-day production activities. The steps required to implement full-scale dyebath reuse as well as optional activities to expand its usefulness are discussed.

Several appendices are included at the back of this manual to assist the user. These include an activities checklist and schedule, forms for use in dyebath reconstitution experiments, computer program listings, and a listing of additional information sources. A glossary of dyebath reuse terms is included.

SECTION II

BASICS OF DYEBATH REUSE BY RECONSTITUTION

DESCRIPTION

The following observation illustrates why reconstitution is a potentially worthwhile reuse technology to be used in conjunction with batch dyeing:

> "Comparison of the dyebath at the beginning and at the end of the dyeing reveals that the major change that occurs during the dyeing is the transfer of dye from the bath to the (product) and an increase in temperature from ambient to (elevated). The dyeing assistants, pH control agents, and the water are essentially unchanged by the dyeing process. It should be possible therefore to analyze the bath following the dyeing process and to determine the quantity of dye that must be added to reconstitute the bath to the desired concentration for the subsequent dyeing" (1).

Dyebath reuse by reconstitution is a modification to the traditional batch dyeing process that takes advantage of this situation by reclaiming the heat, water, unexhausted dyes, and particularly the auxiliary chemicals remaining in an exhausted dyebath for a subsequent dyeing.

This reuse process can be thought of as consisting of four parts:

1. Saving the just-exhausted process bath.
2. Analyzing the bath for residual dyes.
3. Reconstituting the bath by calculating and adding make-up quantities.
4. Reusing the bath for subsequent processing.

These four items are discussed in more detail below.

---

(1) Tincher, Wayne C. Conservation of Water Chemicals, and Energy in Dyeing Nylon Carpet, Project Report - CWRR No. A-064-GA, U.S. Department of the Interior, November 1977.

Saving the Exhausted Bath

Two basic alternatives are available for saving the exhausted dyebath. The dyebath can be pumped to a holding tank, while the product is rinsed in the same machine in which it was dyed. Then as soon as the rinsed product is removed, the dyebath can be returned to the dye machine for the next dyeing cycle.

Alternatively, the dyed product can be pulled from the exhausted dyebath and moved to another machine for rinsing. This alternative eliminates the need for holding tanks and pumps, but requires additional product handling and a spare machine or other equipment for rinsing.

Dyebath Analysis

The exhausted dyebath consists of water, unexhausted dyestuffs, and unexhausted auxiliary chemicals. Water and auxiliary chemical losses are usually small and can generally be estimated.

The unexhausted dyestuffs, however, must be analyzed to determine the exact quantities remaining in the dyebath. This is to ensure that the proper shade is achieved in the next dyeing cycle. Sections V and VI explain how these analyses are performed.

Reconstituting the Bath

Reconstituting the bath consists of adding back the quantities of water, auxiliary chemicals, and dyestuffs needed for the next dyeing cycle. Water is added to replace any lost through evaporation, in the product, or by other means. Auxiliary chemicals are also replenished, generally in proportion to the amount of water added. Any auxiliary chemicals that exhaust during dyeing are added to make up for such exhaustion losses. In general, these quantities can be estimated and do not require exact analysis. Dyestuff make-up quantities are determined by subtracting the quantities present in the exhausted dyebath (as determined above) from the recipe quantities for the next shade to be dyed. These make-up quantities can be calculated by an individual as described in Section VI. However, use of simple desk-top computer programs (Section VII) is an attractive alternative.

Reusing the Bath

Once the bath has been reconstituted and is in place with the product for the next dyeing, conventional dyeing procedures are employed to complete this dyeing. Once the dyeing cycle is completed, the four items described above are repeated. Generally, the bath is reused for four to ten dyeings prior to discharge.

Note that reuse dyeings begin at a higher dyebath temperature than conventional dyeings due to the reuse of the hot dyebath. Experience has shown that this is generally not a problem. Laboratory testing of dyebath reuse should resolve any problems in this area.

Flexibility in production is maintainted with this technology in place. This is because usually no more than half of the dye machines in a typical dyehouse will be dedicated to dyeing using dyebath reconstitution. Even those machines dedicated to dyebath reuse can be used conventionally when special or unusual production schedules require.

BENEFITS

A number of advantages are attributable to dyebath reuse by reconstitution. Auxiliary chemical usage is significantly reduced. Energy and water demands for dyeing are cut. And wastewater volumes and loads are decreased. All of these advantages add up to the most important benefit: cost savings.

Because these cost savings are obtained with a low capital investment, payback periods are generally well under two years with high rates of return on investment. In most instances, auxiliary chemical reductions will make the most important contribution to total cost savings.

Due to the diverse nature of the textile industry, and the widespread applicability of this reuse approach, cost savings as well as capital investments at each mill will vary. Economic analyses for specific mills are presented in Volume 1 and in many of the references listed in Appendix G. These analyses confirm the economic attractiveness of this high-savings, low-expense technology. It is unlikely that the economic aspects of dyebath reuse will restrict its implementation at any but the very smallest of dyehouses. The feasibility of dyebath reconstitution at most mills will depend on technical considerations. It is to these technical aspects of reuse that the remainder of this volume is directed.

SECTION III
DETERMINING APPLICABILITY

Textile dyeing is a complicated process and consequently there are several factors that may affect the implementation of dyebath reuse. Although it is an attractive recycle/reuse technology, it is not applicable to all dyeing operations. The purpose of this section is to enable you to determine whether dyebath reuse may be feasible at your mill.

To achieve this objective, both favorable and unfavorable conditions to dyebath reuse that may exist at a dyehouse are identified. If you decide that potential difficulties do exist, the information presented should help you to determine whether the problem(s) can be solved, or whether the difficulties present a prohibitive barrier to reuse at your facility.

Four important aspects of your dyeing operation will significantly influence the applicability of dyebath reuse at your mill. These aspects are: 1) mode of dyeing (dyeing equipment); 2) dye classes used; 3) production features; and 4) costs. Each of these four areas is explained and discussed below.

MODE OF DYEING

As used here, mode of dyeing refers to whether dyeing is performed at your mill using batch or continuous dyeing processes. Batch dyeing is generally performed using jet, reel, jig, paddle, drum, beck, package, or similar dye machines. Either atmospheric or pressure machines are used. Continuous dyeing is performed on a continuous range. Dyebath reconstitution and reuse, as presented in this manual, is applicable only to batch dyeing, not continuous dyeing. If your mill performs a fair amount of batch dyeing, it has passed the first test in determining whether dyebath reuse will be applicable. However, if your mill primarily or exclusively performs continuous dyeing, reconstitution as discussed in the remainder of this manual is not applicable at your mill.

(Note: Some experimental work has been performed in attempting to apply dyebath reconstitution techniques to rinse-water from continuous dyeing that has been concentrated with technologies such as hyperfiltration. However this application is still under development. Also, due to the efficiency of continuous dyeing, the benefits of reuse for this dyeing method are less than with batch dyeing. For these reasons, this report deals only with dyebath reconstitution applications to batch dyeing.)

DYE CLASSES

To determine whether the dye classes used for dyeing at your mill are appropriate for dyebath reuse, it is first helpful to review the reuse experiences to date for each of these dye classes.

Several types of dyes, classified on the basis of their dyeing properties, are currently used in the textile industry. These include disperse, acid, basic (cationic), direct, reactive, sulfur, and vat dyes. A breakdown of the primary fibers and dyes for products most commonly dyed by batch processes is listed below:

Product	Primary Fibers	Dyes
Ladies' hosiery	nylon	acid, disperse
Mens' hosiery	nylon, acrylic, cotton	acid, basic, direct
Knit fabric	polyester, cotton, nylon, acrylic	disperse, direct, reactive, acid, basic
Yarn	cotton, polyester, acrylic, nylon	direct, reactive, vat, disperse, basic, acid
Carpet	nylon, polyester	acid, disperse
Woven fabric	polyester, cotton	disperse, reactive, vat, sulfur, direct

From this table it can be seen that acid and disperse dyes (used for nylon and polyester fibers) are widely used in batch dyeing. It is not surprising, then, that most of the dyebath reconstitution efforts to date have focused on acid and disperse dyes. Full-scale reuse dyeing experience has also been gained with basic dyes (acrylic fibers) and direct dyes (cotton fibers). Laboratory research with reactive dyes has shown that special techniques are required to reuse these baths. Little research and/or information is available regarding the applicability of reconstitution to the lesser used dye classes such as azoic, mordant, premetallized, sulfur, and vat.

Regardless of which of the dye classes your mill uses, you may be able to employ dyebath reuse, because efforts to date have not shown any dye classes that cannot be used in a reconstitution system. An assessment of the various dye classes as they relate to dyebath reuse at your mill is presented below:

> Acid Dyes, Disperse Dyes. If acid or disperse dyes are the principal dyestuffs used at your mill, then you have a dual advantage in knowing that 1) reconstitution has been successfully and extensively performed with these dyes, and 2) much information is available to you on these applications. Known applications include dyeing nylon carpet with acid dyes; polyester fabric, carpet, and yarn with disperse dyes; and nylon hosiery and carpet with disperse dyes.
>
> Basic Dyes, Direct Dyes, and Reactive Dyes. If significant amounts of dyeing are performed at your facility using any of these three dye classes, available information indicates that dyebath reuse should be feasible. However, implementation of reuse systems for basic, direct, or reactive dyes may require more initial effort by your mill than situations involving acid or disperse dyes.
>
> Basic dye reuse systems should be the easiest to implement since, as with acid and disperse dyes, the reuse procedures are known to be straightforward. Two full-scale reuse applications (acrylic yarn and Nomex fabric) involving basic dyes exist; one uses a known exhaust rate to determine make-up

dye quantitites while the other uses the more traditional analysis approach.

The only full-scale application reusing direct dyestuff baths uses a known exhaust rate procedure rather than analysis. However, the analysis techniques presented in this manual should work with direct dyes.

Reuse of baths containing reactive dyes requires a special technique due to the unique properties of these dyes. The dyebath can only be reused if the fixing bath is kept separate from the dyebath. Successful pilot-scale experiments have been performed but no full-scale applications exist yet.

Therefore, the principal use by your mill of basic or direct dyes should not present a barrier to dyebath reuse. However, with reactive dyes, you can anticipate that more extensive efforts will initially be required (either in-house or by an outside consultant) to develop a reuse system for your dyehouse.

Azoic Dyes, Mordant Dyes, Premetallized Dyes, Sulfur Dyes, Vat Dyes. Little or no guidance in the reuse of dyebaths of these five classes is provided by previous research efforts. If your mill performs most of its dyeing with azoic, mordant, premetallized, sulfur, or vat dyes, you cannot be sure ahead of time whether or not dyebath reuse will succeed. To determine the reconstitution potential of any of these dyes you should first focus on the activities described in Section VI. This will enable you to determine whether you can successfully analyze and determine the residual concentrations of such dyes in exhausted dyebaths at your mill.

PRODUCTION FEATURES

Regardless of the equipment or dye classes you use, certain features of your operation will have an effect on the feasibility or attractiveness of dyebath reuse at your mill. For example, the frequency with which reconstitution series can be scheduled is very important. The following discussion should assist you in determining how much of your dyeing could be performed in a reconstitution series.

The term "reconstitution series" refers to a dyebath that is reused for several dyeings; collectively these dyeings comprise a reconstitution series. To schedule a reconstitution series, each planned dyeing in the series must use the same dyes. For example, suppose that several shades of a particular product that your mill dyes are each formulated from the same combination of three dyes (say Red Dye #1, Yellow Dye #3, and Blue Dye #1 in varying proportions). Then, based on production requirements, various dyeing sequences of these shades could be scheduled in a reconstitution series. Please be aware of an important distinction regarding permissible dye combinations - only shades dyed within a given series require the same dye combination. Other reconstitution series can be performed at your mill using other combinations. As an example, in a typical day your reuse schedule might be as follows:

Series #	No. of Dyeings	Style	Dye Combination for Shades Dyed
1	7	TUV	Red #2/Yellow #3/Blue #1
2	3	TUV	Red #1/Yellow #2/Blue #2
3	4	QRS	Red #2/Yellow #1/Orange #1/Blue #1
4	5	XYZ	Red #1/Yellow #3/Blue #1
5	6	TUV	Red #1/Yellow #2/Blue #2

In addition to these 26 dyeings performed in 5 reconstitution series, you might also have another 40 or so dyeings performed in conventional one-use dyebaths on this day. All dyeing at the mill need not be performed with dyebath reuse.

It should be obvious from the above discussion that the smaller the selection of dyes from which most of the formulations are developed at your mill, the greater the use you can make of dyebath reconstitution. Even if your mill presently uses a large variety of dyestuffs, reformulation of your dye recipes may be possible to reduce the number of dyestuffs used in a portion of your production. This reformulation will simplify implementation and utilization of dyebath reuse at your mill.

The nature of dyeing operations at some mills, however, is not conducive to dyebath reuse, even though it might be technically feasible.

For example, dyebath reuse may not be appropriate for many commission finishers where product, dyes, chemicals, and lot size are constantly changing In addition, mills that operate on only a single shift with only two to three dyeings per machine per day might find reconstitution unattractive.

Many mills use overflow rinsing or cool-down of the product. Cooling water is added to the exhausted dyebath to lower the temperature. While this water does dilute the dyebath, this does not prevent dyebath reuse. It simply means that more auxiliary chemical and dyestuff make-up quantities will have to be added. This hurts the economic benefits somewhat, but in many cases, dyebath reuse will still be cost effective.

Other unique circumstances not discussed above may also exist at your mill. In these instances, you or a consultant will need to determine whether this potential difficulty presents a prohibitive barrier to dyebath reuse at your facility, or whether an alternative can be developed to eliminate, overcome, or work around this obstacle.

COSTS

The three areas evaluated to this point (mode of dyeing, dye classes, and production features) have all considered technical barriers to reuse. Economic feasibility, however, is also an important consideration. Prior to actually performing dyebath reuse tests, it is not possible to accurately determine the costs and benefits of implementing dyebath reuse. Nevertheless, some guidelines can be presented.

Due to the initial fixed costs associated with the purchase of basic analytical equipment and supplies, and initial development costs, the minimum investment to implement dyebath reuse at a small mill is probably $20,000. As a result, your anticipated annual savings due to reduced auxiliary chemical, water/wastewater, and energy costs need to be at least $10,000 (assuming a maximum acceptable payback period of two years). A preliminary economic analysis can be performed at this time to determine whether dyebath reuse might be cost effective at your mill. Figure III-1 presents a worksheet to guide you in making this preliminary estimate. The worksheet assumes cost savings of 40 percent for water/

Item			Estimated Cost
Development Costs			$ 7,500
Lab Equipment/Supplies			7,500
Dyehouse Equipment (pumps, piping, tanks)			
Dye Machine Volume	No. of Machines for Dyebath Reuse	Cost per Machine	
1,000 gal		$11,000	
2,000 gal		$16,000	
4,000 gal		$24,000	
6,000 gal		$30,000	
		TOTAL CAPITAL COST	$

Item	Cost per Dye Cycle	x	Savings	x	Cycles/year with Reuse	Estimated Savings
Water/Sewer		x	0.4	x		$
Aux. Chemicals		x	0.4	x		$
Energy		x	0.1	x		$
					Subtotal	$
					O&M Costs ($2,000 per machine)	-$
					TOTAL SAVINGS	$

Payback Period = Total Capital Cost ÷ Total Savings = years

FIGURE III-1

PRELIMINARY COST WORKSHEET

sewer and auxiliary chemical use, and 10 percent for energy use. It also assumes that the exhausted dyebaths will have to be pumped to holding tanks and later returned to the dye machines for reuse. Section X of this manual presents some ideas that could reduce these capital costs. It is suggested that you read this manual before using the worksheet to estimate your costs. In this way, you will have a better idea of the concepts, equipment, and procedures of dyebath reuse.

After you have performed tests to evaluate dyebath reconstitution and reuse, a more exact cost estimate can be done. This is covered in Section X.

SECTION IV

DEVELOPING AN EVALUATION PROGRAM

Once you have decided that dyebath reconstitution and reuse may be applicable in your dyehouse, the next step is to develop an evaluation program. The purposes of the program are to provide a step-by-step system to allow you to become familiar with the techniques and equipment needed, and to provide an opportunity to test dyebath reuse before full-scale implementation. It is suggested that after reviewing this entire manual, the reader return to this section to outline such an evaluation program.

STEPS IN AN EVALUATION PROGRAM

The five basic steps in an evaluation program are listed below:

1. Select product styles and shades for dyebath reuse.
2. Set up laboratory space for performing tests.
3. Develop dyestuff analysis data.
4. Conduct laboratory-scale tests.
5. Conduct full-scale tests.

Each of these five steps is described in detail below and in the sections that follow. But before describing these steps, there are several considerations that should be taken into account.

Resources Required

Evaluating the feasibility of dyebath reuse will require some mill resources, including space, manpower, time, and expense for needed equipment.

Space. Space requirements for evaluating dyebath reuse are really quite small. Almost all of the laboratory-scale testing can be performed using a single counter top.

Manpower. All activities and monitoring of laboratory-scale dyebath reuse experiments can be performed by a single individual. Full-scale testing can generally be accomplished with the usual number of dyehouse personnel plus one individual again for monitoring the tests.

Time. Depending on the number of styles and shades that you desire to test, the amount of time required for testing will range from about one month upward. This amount of time will generally be sufficient to gain experience with the equipment and procedures, identify and resolve problems, and provide an answer on the technical feasibility of dyebath reuse.

Expense. In addition to the expenses for greige goods, chemicals, water, and energy used in the testing, and the cost of manpower assigned to the testing, there will be some added expense for purchasing laboratory equipment. Depending on the scale of the purchases, the cost might range from $3,000 to $10,000. All of this equipment, however, will be needed if dyebath reuse is instituted full-scale.

Perform Evaluation In-House or Out

The evaluation program can be conducted either in-house or by using an outside consultant (e.g., university with a textile school). There are advantages and disadvantages for each. Performing the evaluation in-house will give mill personnel direct experience with the equipment and procedures. However, it will also require commitment of space, manpower, time, and purchase of equipment as noted above. If any of these requirements becomes prohibitive, it may be possible to find an outside consultant who could perform the evaluation under the mill's direction.

Extent of Evaluation Scope

The extent of the evaluation sc[illegible] can vary. For example, the evaluation could be based on only a few product styles and shades. When these have been successfully dyed using dyebath reuse procedures, then other styles and shades could be evaluated for expanding the amount of dyeing done with the new procedures. Suggestions for the scope of the evaluation are given below and throughout this manual. However, each mill should tailor the evaluation to fit its own goals and budget.

DETAILS OF AN EVALUATION PROGRAM

Selecting Product Styles and Shades for Dyebath Reuse

The first step of an evaluation program is to select product styles and shades that can be dyed with dyebath reuse. You will first want to focus your attention on high-volume styles, those that are dyed frequently and will remain a high-volume item for some time. Within each such style, the shades should be divided into groups. All the shades that are dyed with the same dyestuffs (though in differing amounts) and the same auxiliary chemicals should be grouped together. See Figure IV-1 for an example. The top half lists the recipes for all shades within Style XYZ. The bottom half shows how these shades can be grouped into two separate groups. Note that there are a few "odd" shades that do not fit into either group.

The shades in Group A are all dyed with the same three dyes: Red #1, Yellow #1, and Blue #1. It is now easy to see that to reuse an exhausted dyebath, all that is necessary is to add back the appropriate amount of these same three dyes to dye another shade within Group A. Thus, a series of many dyeings (typically five or more) can be conducted within the Group A shades by reusing the same dyebath.

Similarly, a series of dyeings can be performed within the Group B shades by adding appropriate amounts of Red #1, Yellow #3, and Blue #1. However, crossing over from a shade in Group A to a shade in Group B would generally not be feasible. This is because the exhausted dyebath from the Group A shade would contain a different yellow dye than is needed to dye a Group B shade.

For successful scheduling of reuse dyeings, each group selected for dyeing in this manner should contain shades that are dyed frequently enough so that a series of five or more dyeings could normally be scheduled. For popular styles, this should not be a problem.

If you cannot find any groups of shades that meet the above requirements, it is often possible to reformulate dye recipes to use the same dyestuffs. Again, you would want to select a high-volume style and

STYLE XYZ RECIPES

	Dyestuff o.w.f.				
Shade	Red #1	Yellow #1	Yellow #3	Blue #1	Blue #2
1100	.025	.025	--	.012	--
1102	.021	.020	--	.015	--
1103	.030	.000	--	.015	--
1104	.041	.025	--	.020	--
2201	.075	.150	--	.057	--
2202	.050	.120	--	.065	--
2203	.065	.160	--	.100	--
2204	.108	.195	--	.209	--
3109	.037	--	.006	.003	--
3110	.040	--	.015	.010	--
3111	.040	--	.020	.025	--
3116	.045	--	.026	.040	--
4265	.163	--	.181	--	.480
5511	.171	.175	--	.256	--
5520	.090	.115	--	.290	--
9120	.211	--	.150	.165	--
9121	.220	--	.190	.234	--
9122	.260	--	.235	.305	--
9123	.247	--	.306	.467	--
9507	.315	.163	--	--	.850

All shades dyed with 1% MSP, 1.5% TSP, and 2% leveling agent.

SHADE GROUPS FOR STYLE XYZ

Group A	Group B	Others
1100	3109	4265
1102	3110	9507
1103	3111	
1104	3116	
2201	9120	
2202	9121	
2203	9122	
2204	9123	
5511		
5520		

FIGURE IV-1 GROUPING SHADES FOR DYEBATH REUSE

convert as many shades as possible to using the same dyestuffs. Several cases are known where this has been done not only to enable dyebath reuse but also to simplify purchasing and inventory.

Setting Up Laboratory Space

Prior to testing dyebath reuse within the groups identified above, it is necessary to acquire some equipment and set up a small testing area. Initially, the following equipment is required:

- Spectrophotometer - see Section V
- Glassware and Chemicals - see Section V
- Calculator or Desk Top Computer - see Section VII

Space for this equipment and for conducting laboratory-scale dyeings should be acquired.

Develop Dyestuff Analysis Data

Select one or two groups of shades for initial testing of dyebath reuse. For each of the dyestuffs used in these groups it is first necessary to develop some information that will allow you to analyze an exhausted dyebath and tell how much of each dyestuff remains. The details on this are contained in Section VI.

Conduct Laboratory-Scale Tests

You are now ready to perform some actual reuse dyeings. Select one or two light shades, one or two medium shades, and one or two dark shades from a group. For each of these shades, perform a lab-scale dyeing but do not drain the exhausted dyebath. Instead, reconstitute it using the procedures developed in Section VI, and reuse the dyebath to dye the same shade. Continue doing this until five dyeings of the shade have been performed. The dyed samples can now be compared to evaluate shade matching.

After these single-shade series of dyeings are completed, a multi-shade series can be tested. Start with a light shade and save the exhausted dyebath. Reconstitute it to dye the next darker shade. Continue until five or more dyeings have been completed, and evaluate the results.

Note that it is not necessary to test every single shade in a group. Instead, as noted above, a few light, medium, and dark shades are sufficient. More details on laboratory-scale testing are included in Section VIII.

Conduct Full-Scale Tests

After laboratory-scale testing of dyebath reuse has been successfully completed, you will want to test dyebath reuse full-scale to verify its feasibility. The scope of this testing can vary upward from one or two series of dyeings. The testing need continue only as long as is necessary to demonstrate the feasibility of dyebath reuse or to overcome problems that may arise. See Section IX for more details on full-scale testing.

PREPARING YOUR EVALUATION PROGRAM

This section has outlined the principle features of a dyebath reuse evaluation program; these activities are described in more detail in subsequent sections. As noted at the beginning of this section, after you have reviewed this manual you should outline an evaluation program for your mill. To assist you in developing such a program, a checklist and suggested performance schedule keyed to the five steps introduced in this section is presented in Appendix A.

SECTION V

ABSORBANCE - ITS USE AND MEASUREMENT

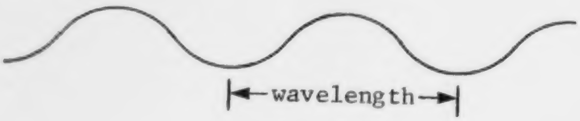
Before a dyebath can be reused, you must be able to determine how much dye remains in the exhausted bath. The concepts and procedures needed to do this are presented in this section and in Section VI.

The basic principle allowing us to analyze dyebaths is that light passing through a solution containing dyes is changed by the dyes. For example, if one holds a glass container with a red dye solution up to ordinary white light, the light emerging from the container appears red. All the other colors of white light (e.g., blue, yellow, green, etc.) have been absorbed heavily by the dye. The red light is absorbed less, and therefore more of it passes through the sample to the eye. In addition, the more red dye that is in the solution, the less the amount of red light that reaches the eye. Thus the red color appears deeper.

All dyestuffs behave in a similar, predictable way. As a result, by measuring the amounts of various colors of light that are absorbed by a dyebath sample, we can determine the amounts of dyes that are in the sample. The following discussion of light absorbance develops the above concepts a little further and presents the basic mathematical equations that are used for dyebath analysis. The rest of this section then describes the analytical equipment and procedures that you will need to make absorbance measurements.

SUMMARY OF LIGHT ABSORBANCE THEORY

Ordinary white light actually consists of a complete spectrum of colors, as can be seen by passing light through a prism. These various colors can be identified generally by names such as red, orange, yellow, green, blue, and violet. They can also be identified scientifically by their wavelength. Light can be thought of as waves. The wavelength is the distance between crests:



The wavelengths for visible light range from about 400 to 700 nanometers (nm), or 16 to 28 millionths of an inch. Red light has longer wavelengths (near 650 nm), blue light has shorter wavelengths (near 480 nm).

If light consisting of only one color, or wavelength, is passed through a dyebath sample, the light will emerge less powerful than it entered. Going back to the example of the red dye solution, if a beam of light with a wavelength of 650 nm (red) is passed through the solution, only a small amount will be absorbed. Most will pass through the sample to the eye, and the sample will appear red. But if light with a wavelength of 480 nm (blue) is passed through, much of this light will be absorbed. For a blue dye solution, the situation would be reversed. See Figure V-1.

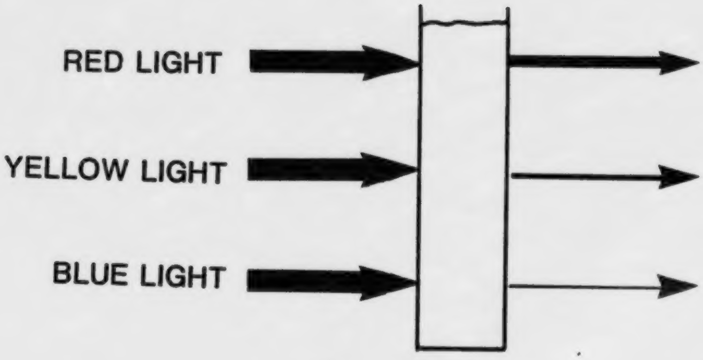
A real dyebath consists of a mixture of several dyes. Thus, if light of a given wavelength is passed through a dyebath containing a red, a yellow, and a blue dye, each of the three dyes will absorb some of the light. In other words, the absorbance at a given wavelength is the sum of the absorbances of the three dyes at that wavelength. Or,

$$A_{total} = A_{red} + A_{yel} + A_{blue}$$

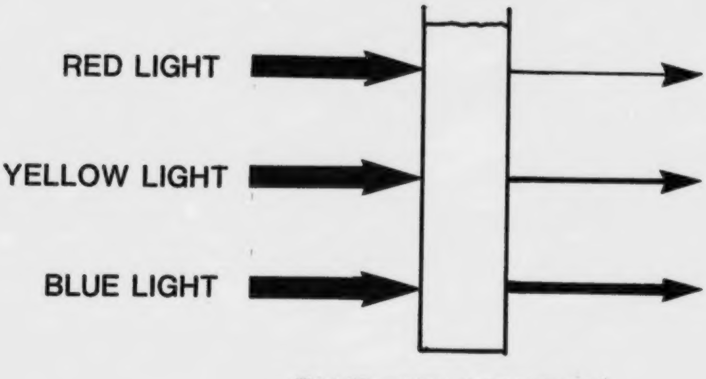
As noted above, the amount of light that each dye absorbs depends on the dye color and the light color or wavelength. It also depends on how much dye is in the dyebath. Recall that in the initial example of the red dye solution, we noted that if more red dye were present in the container, more light would be absorbed and the red color would appear to be deeper. Experiments have shown that doubling the amount of dye will double the amount of light absorbed. The absorbance of light is proportional to the amount of dye in the solution. Mathematically, this is expressed as:

$$A = kC$$

where A is the absorbance, C is the dye concentration (weight per volume), and k is a constant value that is characteristic of the dye. These k-values can be determined by measuring the absorbance, A, of known concentrations of the dye in solution.


RED LIGHT
YELLOW LIGHT
BLUE LIGHT

RED DYE SOLUTION


RED LIGHT
YELLOW LIGHT
BLUE LIGHT

BLUE DYE SOLUTION

FIGURE V–I LIGHT ABSORBANCE BY DYE

Section VI shows how these k-values are developed prior to instituting dyebath reuse in a mill. It also shows how these k-values are used along with absorbance measurements to determine the amount of dye remaining in an exhausted dyebath. The remainder of this section describes how absorbance measurements are actually made.

ANALYTICAL EQUIPMENT

Absorbance is measured using a relatively simple piece of equipment, called a spectrophotometer. Figure V-2 shows the basic parts of a spectrophotometer. It consists of a light source (lamp), a prism or grating to split the light from the lamp into the spectrum of colors, slits to allow only a small part of this spectrum to pass through, a sample cell holder, a detector, and a display.

A spectrum produced by the prism consists of various colors of light, each identified by its wavelength. For example, various shades of yellow light have wavelengths near 580 nanometers. Blue shades have shorter wavelengths, about 480 nm; red shades are about 650 nm. The slit allows only a very narrow range of wavelengths to pass through. For all intents, we can say that it allows light with only a single wavelength to pass. The light is therefore known as monochomatic, because it consists of a single color.

This monochromatic light is then passed through the sample. As explained previously, the dyes absorb a portion of this light. The rest passes through the sample and hits the detector. This generates an electrical signal which is converted to an absorbance reading by electronic circuits. The result appears on the display.

The specifications listed below will allow you to purchase a spectrophotometer that is appropriate for dyebath analysis work.

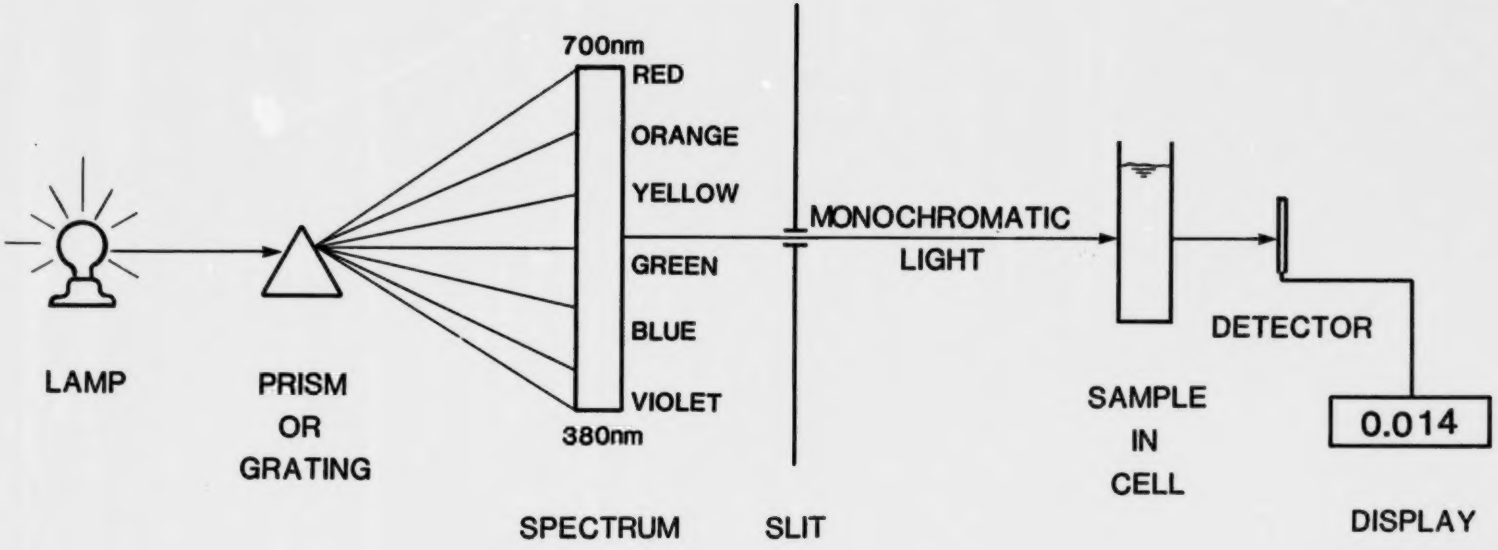

700nm
RED
ORANGE
YELLOW
GREEN
BLUE
VIOLET
380nm
MONOCHROMATIC
LIGHT
0.014
LAMP
PRISM
OR
GRATING
SPECTRUM
SLIT
SAMPLE
IN
CELL
DETECTOR
DISPLAY

FIGURE V-2 SPECTROPHOTOMETER

Suggested Specifications for Spectrophotometer

Wavelength range:	380 to 700 nm or greater
Wavelength accuracy:	2 nm or smaller
Wavelength repeatability:	2 nm or smaller
Spectral slit width:	10 nm or smaller
Absorbance accuracy:	0.003A at 0.4A or smaller
Photometric readout:	0 to 2.00 A digital readout
Accessory output:	Analog in percent transmittance
Accessories:	Multiple sample cell holder (2 cells minimum)

The wavelength range noted above corresponds to visible light. Some spectrophotometers can produce light at wavelengths smaller than 380 or greater than 700 nm. This capability is acceptable, but is not required for dyebath analysis. Wavelength accuracy and repeatability should be 2 nm or less. The spectral slit width or bandwidth should be 10 nm or smaller. A digital readout for absorbance is preferred over a meter readout because the absorbance values of exhausted dyebaths are generally small and difficult to read from a meter. An analog output that is linear with percent transmittance is required if you wish to use an interface to automatically transmit absorbance readings to a computer for calculations; see Section VII. One final accessory that is very helpful is a multiple sample cell holder. This allows you to switch between the "blank" or calibration cell and the dyebath sample cell by operating a simple push-pull lever.

A spectrophotometer of this type will probably cost about $2,600, in 1983 dollars.

MEASURING ABSORBANCE

Measuring the absorbance of an exhausted dyebath is a two-part process. The first part is preparation of a sample of the exhausted dyebath; the second is sample analysis. However, in order to measure the absorbance of exhausted dyebaths, a reference standard must be available. Development of these standards is discussed prior to describing dyebath sample preparation and analysis activities.

Reference Standards (Blanks)

To be meaningful, absorbance readings, using a spectrophotometer, must be made against a reference standard or blank. In analyzing exhausted dyebaths, the most appropriate blank is one that is identical to the exhausted dyebath in all respects with the exception that no dyestuffs are present.

Preparation of a reference standard needs to be performed only once for each product style that you have selected for dyeing with dyebath reuse. For each style perform a bench-scale "dyeing" using the same liquor ratio, auxiliary chemicals, and temperature used in full-scale dyeing. However, do not add any dyestuffs. Following this "mock" dyeing, prepare a reference sample using the same preparation method (as discussed below) that will be used for preparing actual exhausted dyebath samples. Save this reference sample for use as the blank in all future exhausted dyebath analyses for this style.

Dyebath Sample Preparation

Exhausted dyebaths contain, in addition to unexhausted dyestuffs, various "contaminants" such as fiber particles, auxiliary chemicals, fiber finishes, greige good tints, etc. These additional substances can interfere with accurate absorbance readings of residual dyestuffs. Therefore, procedures are required for their removal from samples to be analyzed. Two basic approaches are available to prepare these exhausted dyebath samples for analysis: filtration and solvent extraction. Filtration can be used with water soluble dyes such as acid, basic, and direct dyes. If the filtration procedure does not remove all of the interfering contaminants, then solvent extraction should be used instead. The initial results of laboratory-scale reuse dyeings should quickly tell you if the filtration procedure is sufficient.

Insoluble dyes, such as disperse, vat, and sulfur dyes, will need to be extracted or dissolved in a solvent prior to analysis. Benzene and toluene have been used for disperse dyes. Octanol has been used for acid and basic dyes. Some experimentation with solvents may be needed to select one that is appropriate for use.

The two sample preparation approaches are presented on the following pages. The filtration procedure is described in Figure V-3 and illustrated in Figure V-4. The solvent extraction procedure is described in Figure V-5 and illustrated in Figures V-6 and V-7.

Dyebath Sample Analysis

Once a sample has been prepared (using either filtration or solvent extraction as appropriate), it can be analyzed to determine the absorbance of the exhausted dyebath. To obtain these absorbance values for the dyebath sample, follow the procedure given below:

1. Set the appropriate wavelength on the spectrophotometer wavelength selection dial. Wavelength selection is discussed in Section VI.
2. Place the appropriate blank or reference sample, as discussed above, into a sample cell and place this cell into the appropriate holder in spectrophotometer.
3. Set the absorbance reading to 0.000 by turning the zero-adjust dial.
4. Then place the prepared dyebath sample in its sample cell into the appropriate holder in the spectrophotometer.
5. The sample's absorbance at the selected wavelength will be displayed. Record this value.
6. Repeat steps 1 through 5 for each selected wavelength.
7. Save the blank or reference sample for future use. Dispose of the prepared dyebath sample. Clean all sample cells. It is very important that cells be kept free of all dirt, fingerprints, and that air bubbles are not in the sample when taking absorbance measurements.

The use of absorbance values obtained in the above manner to determine residual dye concentrations in the exhausted dyebath is the subject of the next section.

FILTRATION PROCEDURE

Equipment Required	Quantity	Source	Catalog Number
20-cc Glass Luer-Lok Syringe	2	(1)	14-823-10D
Swinny Filter Holder	2	(2)	XX3001200
Prefilters	2	(2)	AP2501000
Water Filters	2	(2)	HAWP01300
Replacement O-Rings	1	(2)	XX3001201
Replacement Gaskets	1	(2)	XX3001202
Replacement Screen	1	(2)	XX3001210
Sample Cells	4	(1)	14-385-912B

(1) Fisher Scientific Company, Atlanta, Georgia. (404) 449-5050

(2) Millipore Corporation, Bedford, Massachusetts. (617) 275-9200

Approximate total cost (1983) $300.

Procedure

1. Prepare syringe and filter by placing a clean water filter upon the screen; insert a clean prefilter in the O-Ring and place atop water filter, close filter holder and attach to syringe (see Figure V-4).
2. Add exhausted dyebath sample to the barrel of the syringe, and force this sample through the filters by applying pressure to the plunger.
3. Dispose of the first 5 or 10 ml of filtered sample.
4. Use a clean, dry sample cell (cleaned with solvent to remove all traces of dyes and dirt). Force additional sample through the filters into the sample cell.

FIGURE V-3. DESCRIPTION OF FILTRATION PROCEDURE

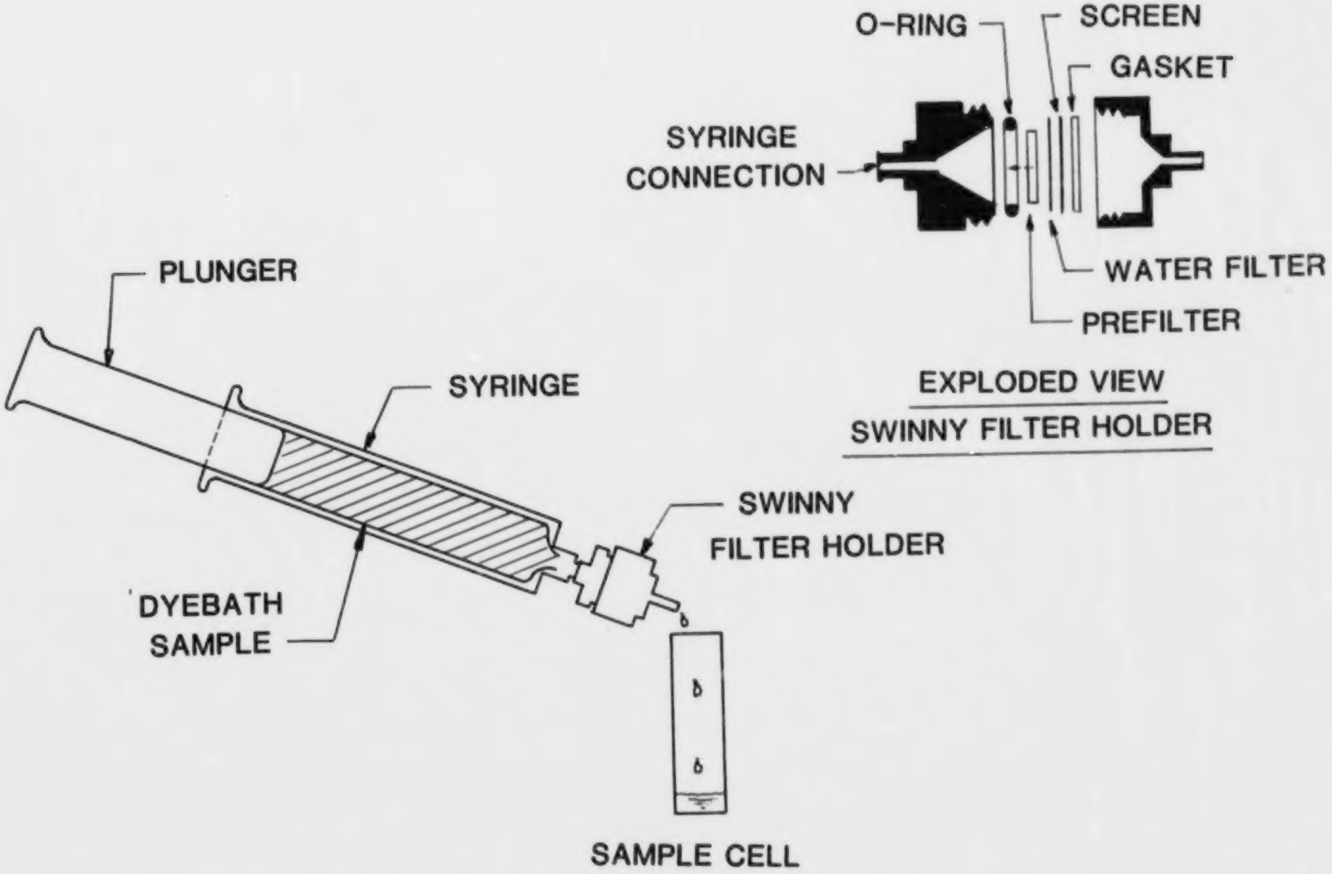

O-RING
SCREEN
GASKET
SYRINGE CONNECTION
WATER FILTER
PREFILTER
EXPLODED VIEW
SWINNY FILTER HOLDER
PLUNGER
SYRINGE
SWINNY FILTER HOLDER
DYEBATH SAMPLE
SAMPLE CELL

FIGURE V–4 ILLUSTRATION OF FILTRATION PROCEDURE

EXTRACTION PROCEDURE

Equipment Required	Quantity	Source	Catalog Number
25-ml Graduated Cylinder	2	(1)	08-550C
250-ml Sample (Separatory) Funnels	2	(1)	10-437-10C
20-cc Glass Syringe	2	(1)	14-823-10D
Ring Stand and Rings	1	(1)	14-670C, 14-052B, and 05-738
Cotton Balls	1 pack	---	--
Table Salt	1 pound	---	--
Solvent	4 liters	(1)	--
Sample Cells	4	(1)	14-385-912B

(1) Fisher Scientific Company, Atlanta, Georgia. (404) 449-5050

Approximate Cost (1983) $350.

Procedure

1. Add 20 ml (25 grams) of salt, 25 ml of exhausted dyebath, and 25 ml of solvent in succession into a clean sample funnel.

2. Place stopper in funnel and shake vigorously for 30 seconds. Allow contents to separate for 30 seconds. Shake vigorously again for 30 seconds. (This mixing action results in extraction of dyes from the dyebath water into the solvent.)

3. Place funnel on ring stand and allow for distinct separation of salt (bottom layer), water (middle layer), and solvent with dyes (top layer). Solvent layer may appear cloudy due to water in the solvent.

4. Remove stopper, open the stop cock and allow the salt and water layers to drain out to sink. Close stop cock.

5. Place two cotton balls in clean, dry syringe. Drain solvent layer from funnel into syringe.

6. Allow solvent to pass through cotton balls in syringe to absorb any remaining water, and collect sample in a clean, dry sample cell as it leaves the syringe.

FIGURE V-5. DESCRIPTION OF SOLVENT EXTRACTION PROCEDURE

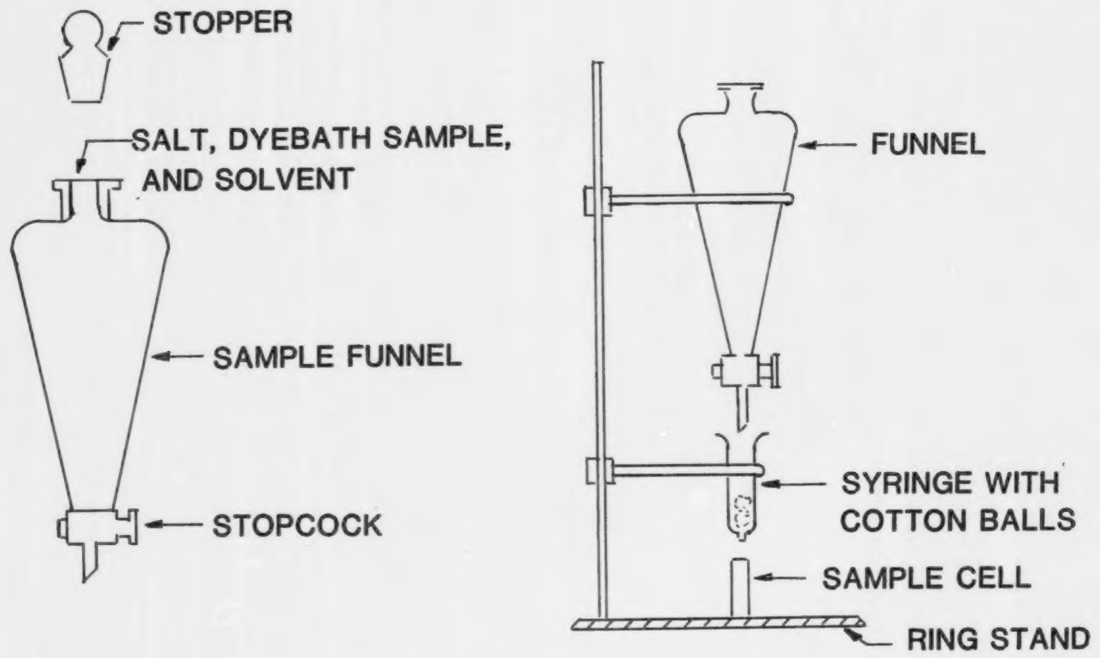
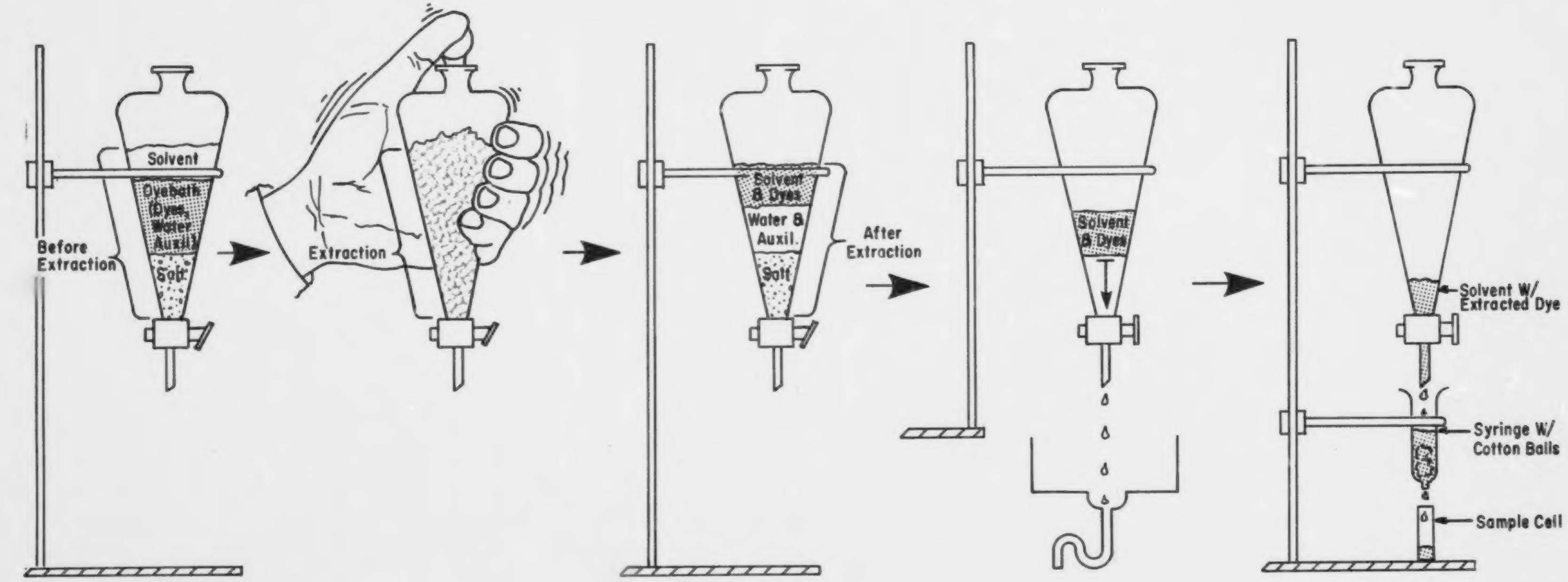

STOPPER
SALT, DYEBATH SAMPLE, AND SOLVENT
SAMPLE FUNNEL
STOPCOCK
FUNNEL
SYRINGE WITH COTTON BALLS
SAMPLE CELL
RING STAND

FIGURE V-6 APPARATUS AND MATERIALS USED IN SOLVENT EXTRACTION PROCEDURE


Solvent
Dyebath (Dyes, Water Auxil.)
Salt
Before Extraction
Extraction
Solvent & Dyes
Water & Auxil.
Salt
After Extraction
Solvent & Dyes
Solvent W/ Extracted Dye
Syringe W/ Cotton Balls
Sample Cell

STEP 1

ADD SALT ,
DYEBATH
SAMPLE , SOLVENT

STEP 2

SHAKE
VIGOROUSLY

STEP 3

ALLOW
SEPARATION

STEP 4

DRAIN SALT
AND
WATER LAYERS
TO SINK

STEPS 5&6

DRAIN SOLVENT
THROUGH
SYRINGE INTO
SAMPLE CELL

FIGURE V-7 ILLUSTRATION OF SOLVENT EXTRACTION PROCEDURE

SECTION VI

ANALYZING YOUR MILL'S DYEBATHS

The ability to determine residual dye quantities in exhausted dyebaths is essential to being able to reconstitute these dyebaths for reuse. This section builds upon the information developed in Section V to explain how to analyze and reuse exhausted dyebaths at your mill. Although the features and concepts associated with dyebath analysis/ reuse are discussed here, to facilitate readability a fair amount of material presenting specific details and examples relative to these discussions has been placed in Appendix B.

It may be convenient to think of the activities involved in analyzing dyebaths as consisting of two phases. Think of the first phase as consisting of one-time only activities that are concerned with developing background information on the dyestuffs you use, and the second phase as consisting of the activities required after each dyeing to analyze the exhausted dyebath.

The activities of the "first phase" provide absorbance information for individual dyes used at your mill. Several steps are required to obtain this information for the various dyes. These tasks are as follows:

1) preparing stock dye solutions for each dyestuff of interest and using these solutions to create diluted samples at various known concentrations;

2) determining absorbance vs. wavelength characteristics for one of the diluted samples of each dyestuff to enable selection of the wavelengths at which exhausted dyebath analyses will be performed;

3) measuring the absorbances of the various diluted dyestuff samples at the wavelengths selected in Step 2 to obtain a plot of absorbance (A) vs. concentration (C) for each dye at each selected wavelength. This last step enables determination of k-values (also known as dye absorbance constants) for each dye at the selected wavelengths. These are the k-values in the equation $A = kC$ introduced in Section V. Each of these preparatory activities is discussed in more detail below;

additional descriptive material for these activities is presented in referenced appendices.

Once these preparatory activities are completed, the information that has been thus developed is used along with absorbance measurements of exhausted dyebaths to determine remaining dye quantities in these dyebaths. The way in which this is done is presented at the end of this section.

PREPARATION OF DYE SOLUTIONS OF KNOWN CONCENTRATION

It was shown in Section V that the absorbance of light was both (a) proportional to the amount of dye in solution, and (b) the sum of the absorbances of the various dyes in the solution. Therefore, by measuring the absorbances of each dye at several known concentrations, information can be developed that will enable you, in the future, to determine the unknown concentrations in exhausted dyebaths. Thus, an important distinction between absorbance measurements made during preparatory activities and those made on exhausted dyebaths is that, in these preparatory activities, the dyestuff concentrations in the solutions being measured are known.

Preparation of these standard solutions, then, is very important, as they are the basis of future activities. It was noted in Section V that the most appropriate blank in sample analysis is one that is identical to the exhausted dyebath in all respects with the exception that no dyestuffs are present. Similarly the most appropriate standards for these preliminary activities are ones that are identical to the exhausted dyebaths in all respects with the exception that known quantities of the dyestuffs are present. Consequently, these dye standards are prepared in a manner similar to that for preparing the reference blanks, with the exception that known quantities of a dye are added to the solution. This procedure is presented in Appendix B.

SELECTING ANALYSIS WAVELENGTHS

As noted previously, analysis of exhausted dyebaths requires absorbance measurements at several wavelengths; the number of wavelengths used normally corresponds to the number of dyes present in the bath.* The wavelengths selected for these measurements are generally those for which one of the dyes has a maximum in absorbance and the other dyes have relatively low absorbances. To determine what these wavelengths are for the dye combinations used at your mill you need to prepare absorbance curves. A description of the preparation of these curves, as well as an example of wavelength selection is presented in Appendix B.

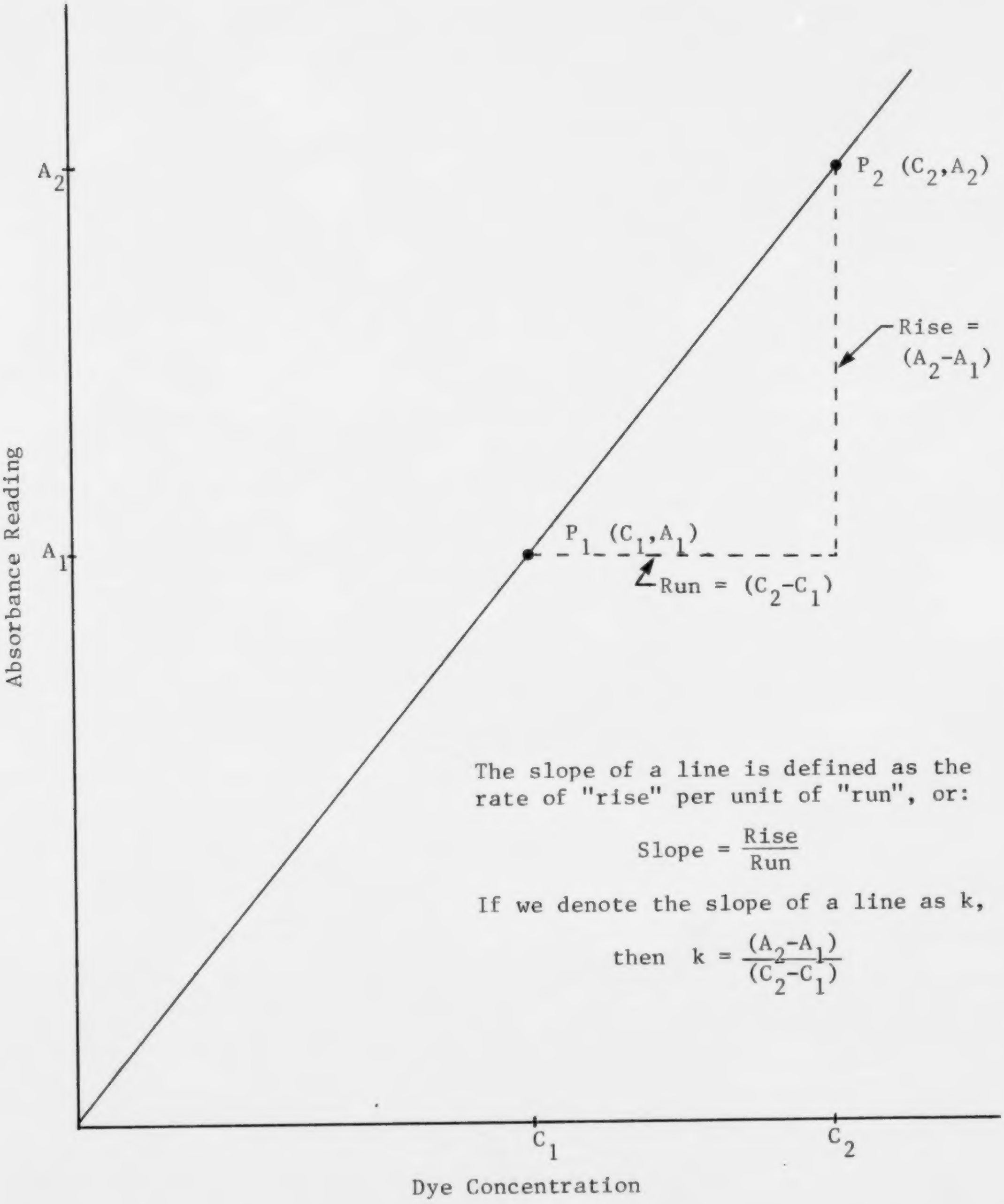
DYE ABSORBANCE CONSTANTS - THE CORNERSTONE OF DYEBATH REUSE

Obtaining Dye Absorbance Constants

Once the optimum wavelengths for absorbance measurements have been selected, dye absorbance constants can be determined. As has been noted, these are the k-values in the equations of the form $A = kC$ that relate absorbance to dye concentration. By rearranging this equation to $k = A/C$, it can be seen that the dye absorbance constant is the slope of absorbance measurements versus known concentrations. This concept is illustrated in Figure VI-1. From this illustration it is seen that at a wavelength where a dyestuff has a relatively high absorbance per unit of dye concentration, the associated k-value will be large; conversely at a wavelength where a dyestuff exhibits relatively low absorbance per given amount of dye, the k-value for the dye at that wavelength will be small.

As noted above, a separate dye absorbance constant is associated with each dye at each wavelength. Thus, to analyze exhausted dyebaths composed of a given three dyes, nine dye absorbance constants, one for each of the three dyes at each of three wavelengths, are required. Likewise, for dyebaths comprised of four dyestuffs, 16 dye absorbance constants (for four dyes at each of four wavelengths) are required.

* It is possible, although unlikely, that exhausted dyebaths may contain residual colors or stains that are not attributable to unexhausted dyes (jute stain due to carpet backing is an example). This situation is easily identified by observing whether there is a residual color in the blanks prepared previously. Since a situation of this sort is rarely encountered, it is not discussed in this section. Information on wavelength selection for these infrequent conditions is presented in Appendix B.


A_2
P_2 (C_2, A_2)
Rise = $(A_2 - A_1)$
Absorbance Reading
A_1
P_1 (C_1, A_1)
Run = $(C_2 - C_1)$
C_1
C_2
Dye Concentration

The slope of a line is defined as the rate of "rise" per unit of "run", or:

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}}$$

If we denote the slope of a line as k,

$$\text{then} \quad k = \frac{(A_2 - A_1)}{(C_2 - C_1)}$$

FIGURE VI-1 GRAPHICAL ILLUSTRATION OF k-VALUE CONCEPT

The way in which each of these dye absorbance constants is calculated is fairly simple. Absorbance measurements are made at a selected wavelength on each of the solutions of known concentration prepared for a given dye. These data are tabulated. The resultant slope (i.e., k-value) can then be determined using either mathematical or graphical methods. These methods and an example calculation are presented in Appendix B.

Verifying Accuracy of Dye Absorbance Constants

Since dye absorbance constants are so important to dyebath reuse activities, you may want to verify their accuracy before performing reuse dyeings. This can be done very easily. To an exhausted dyebath without any dyes (such as was used to prepare blanks and dye standards) add known quantities of all (three) dyes. Make absorbance measurements of this solution in the usual manner at the (three) selected wavelengths, and calculate dye concentrations (as will be described below). Compare these calculated concentrations to the known quantities that you added. They should closely agree. If they do not, you will need to repeat the various activities associated with dye absorbance constant development, including perhaps dye standard preparation.

Using Dye Absorbance Constants

Once you have determined the dye absorbance constants, you are able to analyze exhausted dyebaths. By measuring the absorbances of the dyebath at the previously selected wavelengths, and solving a set of equations, you can determine the residual concentrations of each dye in the bath.

The reason this is so is due to the previously described characteristics of absorbance: 1) that the absorbance of light by a given dye is proportional to the amount of that dye in solution; and 2) that the total absorbance of light in a dyebath at a given wavelength is due to the sum of the absorbances by each of the individual dyes. Because of the first characteristic we are able to develop dye absorbance constants that represent the proportional amount that absorbance increases for an increase in dye concentration. Thus, rearranging the previously presented equation for a single dye at a single wavelength, $A = kC$, we obtain $C = A/k$. Since we can determine k and measure A, once these two numbers are obtained we can obviously calculate the concentration of a single dye in an exhausted bath containing only one dye. However, most dyebaths are comprised of several (often three) dyes. This is where the second characteristic, that absorbance is additive, comes into play. Suppose we have a red dye (r), a yellow dye (y), and a blue dye (b), and we have selected wavelengths w1, w2, and w3 for our absorbance measurements. We will call the measured absorbance A_{w1} for a bath containing these three dyes and measured at wavelength w1. Since absorbance is additive, A_{w1} is the sum of the absorbance contributions at this wavelength of the red dye (A_{w1r}), the yellow dye (A_{w1y}), and the blue dye (A_{w1b}). Thus:

$$A_{w1} = A_{w1r} + A_{w1y} + A_{w1b}$$

Although we cannot separately measure A_{w1r}, A_{w1y}, and A_{w1b} in a dye mixture, we do know that $A_{w1r} = k_{w1r}C_r$, where k_{w1r} is the dye absorbance constant we have previously determined for this dyestuff at this wavelength, and C is the (unknown) concentration of this dyestuff in the dyebath we are analyzing. Thus, by substitution:

$$A_{w1} = A_{w1r} + A_{w1y} + A_{w1b} = k_{w1r}C_r + k_{w1y}C_y + k_{w1b}C_b$$

Similarly, for absorbance measurements at wavelengths w_2 and w_3,

$$A_{w2} = k_{w2r}C_r + k_{w2y}C_y + k_{w2b}C_b$$
$$A_{w3} = kw3rC_r + k_{w3y}C_y + k_{w3b}C_b$$

We know all the (nine) k-values in these (three) equations from our previous efforts, and we can analyze an exhausted dyebath of interest to determine these (three) absorbance values. The only values we don't know are the concentrations of the dyes, in this case C_r, C_y, and C_b. These must be determined by calculation. Mathematically, this situation is referred to as being a case of n simultaneous liner equations with n unknowns, where n is any number (in our case 3). The unknown values in such a situation can always be determined. However, these calculations are laborious to perform by hand. Therefore, programs to solve a system of simultaneous equations for desk-top computers and sophisticated hand-held calculators are generally used. A discussion and program for using a desk-top computer in such a manner is presented in Section VII. If you wish to use a hand-held calculator, you should consult the operator's manual for this device to determine whether it has the capability to solve simultaneous linear equations, and if so, what the appropriate instructions are. An illustrative example showing the steps involved in solving these equations by hand to determine dye concentrations is presented in Appendix B.

CALCULATION OF DYE AND AUXILIARY CHEMICAL MAKE-UP QUANTITIES

Dye Make-up Quantities

Dyestuff quantities required to reconstitute dyebaths are determined in the following manner. The calculated concentration (gram/liter) of a given dyestuff is multiplied by the volume of dyebath to be reused to give the total quantity of the dye being reused. This quantity is then subtracted from the total required quantity of that dye as defined by the recipe for the shade to be dyed; the difference in these two quantities is the amount of dyestuff added as make-up for the next dyeing.

Auxiliary Chemical Make-up Quantities

A detailed and very accurate analysis of the auxiliary chemical quantities remaining in the dyebath is not needed nor would it be easy to obtain. Instead, the amounts of auxiliary chemicals required to be added to reconstitute the dyebath can be estimated to sufficient accuracy by using a simple equation. The original quantity of auxiliary chemicals is still contained in the exhausted dyebath at the time of analysis. If all this dyebath is reused, then no make-up auxiliary chemicals are required. If only a portion of the dyebath is reused, then the percent auxiliary chemical make-up is calculated as:

$$P = 100 \left[1 - \frac{V_r}{V_f} \right]$$

where P = percent make-up of auxiliary chemicals

V_r = volume of dyebath reused

V_f = final volume of dyebath (at time of dye analysis)

In the case where the dyebath has been diluted, V_f is the sum of the dyebath volume immediately after dyeing plus the volume of any water added.

In most mills, these volumes remain relatively constant and thus the auxiliary chemical make-up percentage need be calculated only once, or when drastic dyeing procedure changes are made.

Certain auxiliary chemicals will completely exhaust or vaporize during dyeing and the percent make-up will thus be 100 percent. Examples are defoamers, volatile chemicals, and finishes that adsorb onto the textile fibers.

Section VII presents a computer program for easily calculating dye and auxiliary chemical make-up quantities.

SECTION VII

COMPUTERIZED DYEBATH REUSE

The reconstitution and reuse of dyebaths requires the following data analysis and processing steps to be performed:

1. Solution of three or more simultaneous linear equations, based on absorbance data, to determine dyestuff concentrations.
2. Conversion of these concentrations to weights of dyestuff in the recycled dyebath.
3. Computation of make-up quantities for the next dyeing based on recipe quantities, recycled quantities, and estimated auxiliary chemical exhaustion rates.

These steps must be performed quickly and accurately to maintain a normal production schedule incorporating dyebath reuse. Because of the complexity of the calculations and the need for accuracy and speed in performing them, an automatic data processing system, based on a desk-top computer, was developed.

The basic components of the data processing system are given below, and their interrelationship is shown in Figure VII-1. The operator, through the keyboard, instructs the computer to begin dyebath reuse data processing. The computer, through its display (CRT screen), requests information from the operator, such as the product style, shade, weight, etc. The operator responds to these questions by typing his responses on the keyboard. At the appropriate times, the computer instructs the interface to collect data from the spectrophotometer. The computer processes this data, searches its data storage files for the appropriate dyeing recipes, calculates the required make-up quantities and prints the results on the printer. The system also allows the operator to add or change dye recipes. Further details on the individual components and the computer programs are presented below.

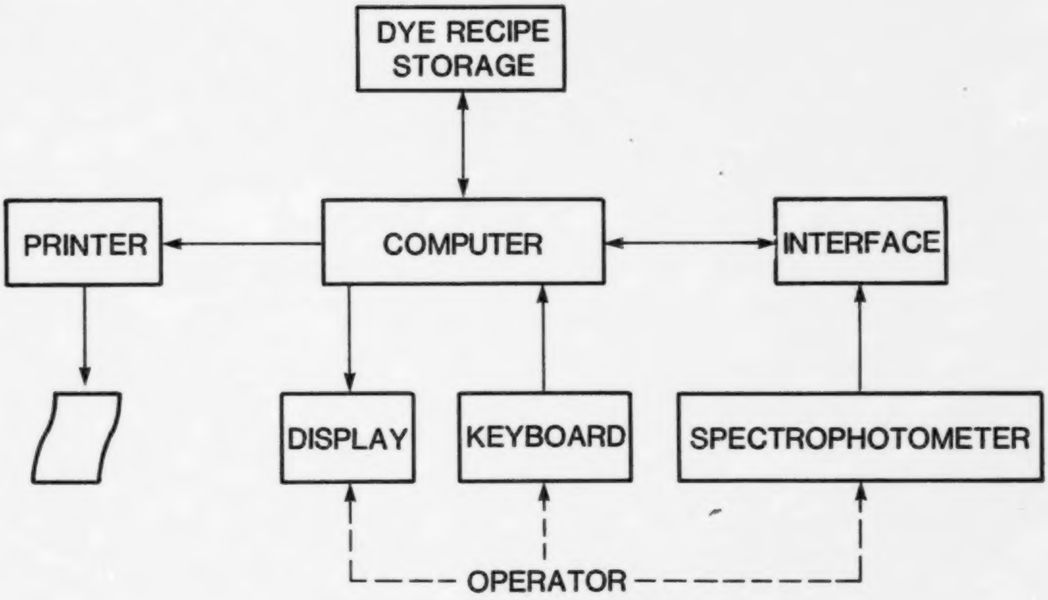

DYE RECIPE STORAGE
PRINTER
COMPUTER
INTERFACE
DISPLAY
KEYBOARD
SPECTROPHOTOMETER
OPERATOR

FIGURE VII-1 AUTOMATIC DATA PROCESSING SYSTEM

COMPUTER EQUIPMENT

Several basic pieces of equipment that you will need to set up a computerized dyebath reuse system are described below.

Computer

An understanding of how computers work is not needed to use one for dyebath reuse calculations. However, the computer that you purchase must be capable of running the programs and performing various data input or output functions. These include storing dye recipes, printing out make-up quantities, displaying information to the operator, and accepting his responses.

A reputable computer dealer should be able to assist you in selecting, assembling, and testing the various components needed, based on the minimum specifications given below:

Computer CPU	16 bit
Internal Memory	128k bytes RAM
Display	monochrome, 24 lines, 80 characters
Keyboard	alphanumeric
Printer	80 column, with serial or parallel interface to computer
Other I/O Ports	EIA RS-232C serial input/output port with baud rate of 1200 bits/second.
Disk Drives	Single 5-1/4 inch floppy disk drive
Software	MS-DOS, MS-BASIC (Microsoft, Inc.)

The estimated current cost for such a system is about $3,500. Many manufacturers produce such computers, but names are not given here due to the fast changing nature of the computer market.

Interface

The interface is a device that takes absorbance readings from the spectrophotometer and transmits this information to the computer.

It is a time-saving but optional device. Without it, the operator will have to read the spectrophotometer display and manually type the absorbance readings into the computer. This option is discussed later in this section.

The dyebath reuse programs presented in this manual are written for a particular interface, the "Smartface", manufactured by Analytical Computers in Glen Ellyn, Illinois. This interface is easily calibrated and connected to both the spectrophotometer and computer. Ordinary wire is used for the connection to the spectrophotometer, and a standard 25-pin cable is used for the connection of the interface to the computer. The estimated current cost for the interface and cables is about $900.

COMPUTER PROGRAMS

The dyebath reuse computer program is listed in Appendix F. It is written in the BASIC computer language. A few minor modifications may be needed to use the program with your computer and spectrophotometer. These are described below.

Number and Names of Styles

The names of up to ten product styles for which you will be performing reuse dyings should be listed in lines 200 and 210. Should your reuse system eventually cover more product styles, the number "10" that occurs in the following lines should be changed to the new number: 140, 170, 560, 610, 1270, 1320, 6840, and 6890.

Manual Input of Absorbance Readings

If you decide not to use an interface, but rather wish to manually input absorbance readings into the computer, there are two program changes that need to be made. For lines 4900 to 5030, use the alternate lines listed on that page. Also, for lines 4300 to 4660, substitute the alternate lines listed on that page.

Interface Set-up

Three items must be checked here. The data transfer rate (baud rate) dial on the interface should be set to 1200. Second, the spectrophotometer's auxiliary analog output should be connected to channel #1 of the interface. And third, the number "4" that appears in program lines 4960 and 4970 may need changing. This will depend on the voltage output of the spectrophotometer. Use the following values:

Spectrophotometer Analog Output	Program Value
0 - 1 volt	4
0 - 100 millivolts	3
0 - 10 millivolts	2
0 - 1 millivolt	1

Printer Codes

Special print codes, preceded by "CHR$", appear in lines 2000 to 2880. These codes are compatible with printers manufactured by EPSON, but may not be compatible with all printers. The codes call for underlining or for special type faces. They should not interfere with the operation of other printers, but can be deleted from the program if problems in the printed output do occur.

USE OF DYEBATH REUSE PROGRAM

When the dyebath reuse program is run, the information on Figure VII-2 appears on the screen.

For this Figure and those following, information and questions displayed by the computer are in bold type. The operator's responses are in normal but underlined type.

To perform a reuse dyeing, the operator types in "A". The computer first asks for information concerning the last dyeing (the dyebath of which is to be reused). See Figure VII-3.

The computer then asks the operator to set the wavelength of the spectrophotometer and take readings. The operator is asked to verify the absorbance reading that the interface has transferred to the computer. See Figure VII-4.

The computer then calculates the quantities of dyestuff remaining in the exhausted dyebath and reports this information along with the percent dyestuff exhaustion to the operator. See Figure VII-5. This information is useful in evaluating whether any problems occurred in the last dyebath. Such problems would be indicated by low percent exhaustions and could be due to pH changes or other causes.

The system then asks the operator for data on the next dyeing, and asks if any additional auxiliary chemicals were added in the previous dyeing (auxiliary chemical adds). See Figure VII-6. Finally, the computer calculates an exhaustion rate for auxiliary chemicals and asks the operator if he wishes to make any changes. In this case, the operator responds that all auxiliary chemicals are exhausted 25 percent except for the defoamer. He assumes that all the defoamer is lost in the previous dyeing. See Figure VII-7.

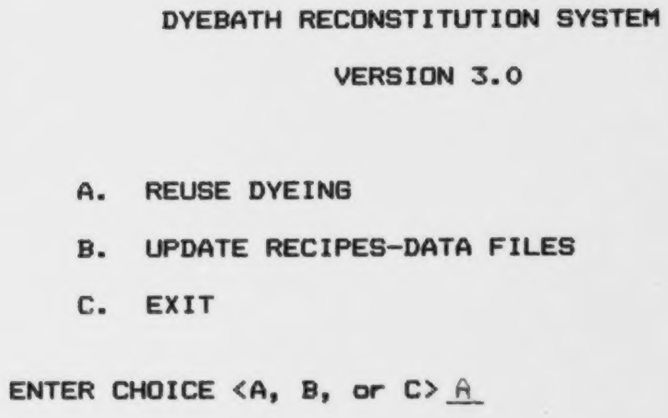
The computer now has all the information it needs to compute and print the make-up quantities for the next dyeing. An example printout is shown in Figure VII-8. The format of this printout can be varied to suit a specific mill by modifying program lines 2000 - 2880. The format could also be tailored so that it could be printed directly on standard preprinted forms used by the mill.

Adding and Changing Dye Recipes

Procedures and examples for adding dye recipes to the computer's memory and for changing those recipes are given in Appendix E.

Program Comments

The computer program is designed to guide the operator through the various steps. The computer gives the operator an opportunity to verify all information that he has input. Therefore, the probability of a major mistake is minimized. The best advice, however, is to become familiar with the workings of the program by actual use. This can be done during the lab-scale experiments. Then, by the time that dyebath reuse is implemented full-scale, the use of the programs will have become familiar.



```
                 DYEBATH RECONSTITUTION SYSTEM

                          VERSION 3.0


            A.   REUSE DYEING

            B.   UPDATE RECIPES-DATA FILES

            C.   EXIT

ENTER CHOICE <A, B, or C> A
```

FIGURE
VII-2

```
INPUT LAST STYLE AND SHADE DYED

 1     STYLE #1
 2     STYLE #2
 3
 4
 5
 6
 7
 8
 9
 10
TYPE NUMBER OF STYLE 1

INPUT SHADE NUMBER 33312

STYLE #1  SHADE 33312

CORRECT? <Y or N>  Y

INPUT WEIGHT OF LAST DYEING (Pounds) 2200

 2200 Pounds, Correct? <Y or N>  Y


INPUT VOLUME OF DYEBATH TO BE REUSED (gallons) 5000

 5000 Gallons, Correct? <Y or N>  Y



INPUT TOTAL VOLUME OF EXHAUSTED DYEBATH
INCLUDING ANY OVERFLOW LOSSES (Gallons)  6670
```

FIGURE
VII-3

```
SET WAVELENGTH TO 400 nm

INSERT 'BLANK' CUVETTE AND SET ABSORBANCE AT 0.000
HIT 'RETURN' WHEN READY TO CONTINUE


INSERT SAMPLE CUVETTE
HIT 'RETURN' WHEN READY


ABSORBANCE AT 400  nm = 0.006
CORRECT? <Y or N>  Y
```

```
SET WAVELENGTH TO 540 nm

INSERT 'BLANK' CUVETTE AND SET ABSORBANCE AT 0.000
HIT 'RETURN' WHEN READY TO CONTINUE


INSERT SAMPLE CUVETTE
HIT 'RETURN' WHEN READY


ABSORBANCE AT 540  nm = 0.011
CORRECT? <Y or N>  Y
```

```
SET WAVELENGTH TO 640 nm

INSERT 'BLANK' CUVETTE AND SET ABSORBANCE AT 0.000
HIT 'RETURN' WHEN READY TO CONTINUE


INSERT SAMPLE CUVETTE
HIT 'RETURN' WHEN READY


ABSORBANCE AT 640  nm = 0.004
CORRECT? <Y or N>  Y
```

FIGURE
VII-4

```
DYE              CONC %           EXHAUST %
~~~              ~~~~~~           ~~~~~~~~~
ORANGE            1.343464E-05      99.4
RED               8.994066E-05      96.4
BLUE              1.925705E-05      99.2
```

FIGURE
VII-5

```
INPUT NEXT STYLE AND SHADE

 1    STYLE #1
 2    STYLE #2
 3
 4
 5
 6
 7
 8
 9
 10
TYPE NUMBER OF STYLE  1

INPUT SHADE NUMBER  33314

STYLE #1  SHADE 33314

CORRECT? <Y or N>  Y

INPUT WEIGHT OF NEXT DYEING (Pounds)   2200

 2200 Pounds, Correct? <Y or N>  Y




WERE ANY ADDITIONAL AUXILIARY CHEMICALS ADDED DURING
THE PREVIOUS DYE CYCLE (Chemical Adds) ?  N
```

FIGURE
VII-6

```
THE SYSTEM WILL ASSUME A 25 % LOSS FOR ALL AUXILIARIES.
DO YOU WISH TO CHANGE THIS TO A DIFFERENT LOSS PERCENTAGE
<Y or N> ?  N
```

```
THE SYSTEM WILL ASSUME THE FOLLOWING LOSSES FOR THE
AUXILIARY CHEMICALS IN THE LAST DYEBATH:

 1 M.S.P.    25 %
 2 T.S.P.    25 %
 3 Sequest.  25 %
 4 Level   A 25 %
 5 Level   B 25 %
 6 Defoamer  25 %
 7           25 %

TO MAKE ANY CHANGES, TYPE NUMBER OF AUXILIARY CHEMICAL
HIT RETURN TO CONTINUE  6
TYPE NEW LOSS PERCENTAGE <0 to 100> 100
```

```
THE SYSTEM WILL ASSUME THE FOLLOWING LOSSES FOR THE
AUXILIARY CHEMICALS IN THE LAST DYEBATH:

 1 M.S.P.    25 %
 2 T.S.P.    25 %
 3 Sequest.  25 %
 4 Level   A 25 %
 5 Level   B 25 %
 6 Defoamer  100 %
 7           25 %

TO MAKE ANY CHANGES, TYPE NUMBER OF AUXILIARY CHEMICAL
HIT RETURN TO CONTINUE
```

FIGURE
VII-7

```
                         EPA - IERL
                      CARPET MILL C-2
                    SVERDRUP & PARCEL

                                                        10-14-1983
                                                         10:08:55

LOT:________________

PRESENT STYLE: STYLE #1          SHADE: 33314    WEIGHT:  2200 lbs

PREVIOUS:      STYLE #1                 33312             2200 lbs

VOLUME RECYCLED: 5000 GALLONS

ADD QUANTITIES (Pounds)

DYESTUFF      RECYCLE    RECIPE      ADD
-----------------------------------------
ORANGE           0.01      1.00    0 lbs, 6952 gr
RED              0.04      1.03    0 lbs, 6975 gr
BLUE             0.01      0.96    0 lbs, 6688 gr

AUXILIARY     RECYCLE    RECIPE      ADD
-----------------------------------------
M.S.P.          16.50     22.00      5.50
T.S.P.          16.50     22.00      5.50
Sequest.         8.25     11.00      2.75
Level  A        16.50     22.00      5.50
Level  B        33.00     44.00     11.00
Defoamer         0.00     22.00     22.00

                             EXPERIMENTAL DATA

WAVELENGTH     ABSORBANCE          DYESTUFF     CONCENTRATION %     EXHAUST %

   400           0.006              ORANGE       1.343464E-05         99.44
   540           0.011              RED          8.994066E-05         96.37
   640           0.004              BLUE         1.925705E-05         99.17
```

FIGURE
VII-8

SECTION VIII

LABORATORY DYEBATH REUSE EXPERIMENTS

Laboratory activities are a very important stage in the evaluation of dyebath reconstitution and reuse at a mill. Laboratory tasks associated with analyzing dyebaths are described in Section VI. This section discusses the "whys" and "hows" of performing actual reconstitution series dyeings on a small scale prior to attempting full-scale trials.

IMPORTANCE OF LABORATORY EXPERIMENTS

In all likelihood your mill or company currently performs some experiments on a small scale to evaluate new dye recipes and procedural modifications before implementing these changes into production activities. For many of the same reasons as those associated with your conventional evaluations, and some additional ones, small-scale reconstitution experiments are important. The purposes for performing laboratory-scale experiments are reviewed below.

Dyebath analysis for reconstitution involves the performance of some activities that will be unfamiliar to people at your mill. Therefore, a principal objective in performing reconstituted laboratory dyeings is to enable personnel to gain experience in performing dyebath analyses and calculations associated with dyebath reconstitution and reuse; any mistakes that are made during this learning period will not result in lost production.

Laboratory dyeings require less labor and materials than production dyeings. In addition, because they are more easily controlled and performed, they are a good way to develop information quickly and inexpensively, without interfering with production schedules. For example, a preliminary assessment of the shade matching accuracy attainable at your mill from reuse dyeings can be made with a minimum effort. If difficulties develop at this stage with dyebath analysis or reuse procedures, the problems can be more easily identified and possible solutions developed. Other aspects of dyebath reuse, such as initial dyebath temperature and reconstitution series length/sequencing, can also be evaluated without risking production lots.

CONDUCTING LABORATORY EXPERIMENTS

Laboratory reconstitution experiments should simulate full-scale dyeing procedures and conditions as closely as possible. Therefore, the form these experiments should take is to a certain extent mill-specific. You and others at your mill are best qualified to determine the details of the laboratory experiments. The following paragraphs are intended to provide guidance in developing and performing these experiments at your mill.

Preparation .

To a great extent, the activities described in previous sections comprise much of the necessary preparation required for laboratory reuse experiments. The approach for selecting the styles and shades to be dyed in your experimental program is discussed in Section IV. The development of dyestuff characteristics is described in Section VI. Acquisition and use of necessary analytical equipment is presented in Sections V and VII. However, some additional decisions and activities are required in preparation for laboratory dyeings.

Experimental Levels. There are at least two experimental levels at which laboratory dyeings can be performed. The smaller and simpler level, involving laboratory beakers or similar minimal units, is commonly referred to as bench-scale dyeing. An intermediate level, employed after bench-scale dyeing and prior to full-scale dyeing, utilizes small replicas of full-scale dye machines and is referred to as pilot-scale dyeing. Either or both of these experimental levels may be appropriate for your laboratory reuse dyeings. Therefore, the first decision you need to make is how these laboratory dyeings will be performed. Your options may be influenced or limited by available equipment and full-scale dyeing procedures. If you currently have a set approach for experimenting with new shades, products, and procedures and then "scaling up," then you should follow this approach for the reuse dyeing experiments.

Procedures. Once you have selected the level/equipment at which you will begin laboratory reuse experiments, you will need to develop procedures for these dyeings. The procedures that you develop for these experimental reuse dyeings will generally be similar to the procedures you follow for conventional test dyeings. The steps involved will resemble the listing that follows:

Step 1. Add volumes/quantities of chemicals, dyes, greige goods, and water in usual sequence, amounts, and proportions for this level of dyeing (first dyeing in series only.)

Step 2. Perform dyeing in your usual manner for this level of dyeing. For example use the same heating methods, dyeing temperatures, dyebath monitoring and adjustment procedures, and dyeing times as if this were a conventional laboratory dyeing.

Step 3. Upon completion of the dyeing either (a) remove the dyed goods from the beaker or dyeing unit, or (b) transfer the exhausted dyebath to an identical beaker or dyeing unit for the next dyeing. Rinse, dry, and evaluate dyed product using your usual procedures.

Step 4. Record the exhausted dyebath volume. Collect a small sample of this dyebath for absorbance measurements. Perform filtration or solvent extraction of this sample if necessary. (See Section V for a description of these sample preparation techniques.)

Step 5. Make absorbance measurements and calculate quantity of dye remaining in exhausted dyebath and amount required for the next dyeing. (See Section V for performance of absorbance measurements, Sections VI and VII for calculation methods.)

Step 6. Add appropriate/calculated amounts of make-up water, greige goods, chemicals, and dyes for next dyeing.
(Repeat Steps 2 through 6 for subsequent dyeings in series.)

This listing is intended only as a general guide to assist you in developing a procedure listing appropriate to your specific situation. In addition, you may find that minor modifications to your original or anticipated procedures are desirable once you have performed a few reuse dyeings. It is important, however, that once a dyebath reuse procedure for an experimental level has been refined, all unnecessary variables from dyeing to dyeing be eliminated, or constrained as much as possible. In particular, the volume of water in the dyeing unit should be maintained relatively constant from dyeing to dyeing, particularly prior to removal of the sample for absorbance measurements, for dyeings where the same weight and style of goods are dyed repetitively. This is important to maintain relatively constant auxiliary chemical concentrations and to simplify make-up calculations.

Scheduling. A final preparatory activity prior to performing laboratory dyeings is to schedule the several experimental series that will be performed. The initial series should consist of single shades dyed repetitively until five or so dyeings of that shade have been obtained. At least one light, one medium, and one dark shade should each be dyed this way. After several of these single-shade series of reconstituted dyeings are completed, multi-shade series should be scheduled. The shades dyed in the respective baths of these series should progress gradually from light to dark.

Performance

Dyebath reconstitution procedures will be unfamiliar to the personnel performing these techniques. To help avoid frustrating mistakes and errors, distractions due to other unrelated laboratory tasks should be minimized during the first several reuse dyeing series. Procedures detailing the necessary steps and activities for the dyeing cycle in a reuse series should be written down and made readily available to personnel so they can refer to them as the dyeings are performed. Additionally, forms should be used to record pertinent information for each dyebath in a series. An example of such a form is presented in Appendix C.

ASSESSING LABORATORY RESULTS

Shade Matching

As mentioned previously, a key objective of these laboratory experiments is to assess your ability to obtain satisfactory shade matching results with reuse dyeings. You may be able to evaluate these dyeings with a color measuring instrument if you have one available, or in other ways that your mill has found suitable, such as visual comparison. Although you undoubtedly have a mill standard for each of the shades in your inventory, in some instances the first dyeing in a single shade series may be more appropriate for use as a standard in evaluating laboratory reuse dyeings of that shade. This is because the first dyeing in a reconstitution series is a conventional laboratory dyeing; if something inherent in your laboratory dyeing process prevents these conventional dyeings from exactly corresponding to your mill standard, it is unrealistic to expect reuse dyeings to meet the standard either. These deviations from mill standards are particularly likely with bench-scale experiments. However, successful reuse dyeings should be repeatable; in other words the second, third, fourth, etc. dyeing in a single-shade reuse series should closely match the first (conventional) dyeing.

If successful shade matching has been obtained once all the planned laboratory experiments have been completed, and there are no other significant unresolved problems, preparations for full-scale trials at your mill should begin. However, if difficulties with shade matching or other factors develop during these laboratory dyeings, they need to be resolved and successful dyeings completed before full-scale trials begin.

Problem Response

Alternatives. There is always the possibility that problems of one sort or another will be encountered during the laboratory dyebath reuse trials at your mill. An important objective of these laboratory experiments is to identify and resolve any problems with dyebath reuse that may be present as a result of particular factors at your mill, or as a result of initial reuse/analytical procedures and techniques employed in these dyeings.

If a significant problem is encountered in these experiments you basically have three options: a) attempt to identify the cause of the problem and resolve it using mill personnel; b) consult with outside experts; or c) end the reuse experiments. The decision to end the reuse experiments should only be considered if the first two options prove unsuccessful. The first option alone, or in conjunction with the second option are recommended. This recommendation is based on experiences at Mill C-2 (see Volume 1) and elsewhere where unanticipated problems have occured. Easily implemented modifications have usually solved these problems once the causes were identified. The more difficult and time consuming task is to identify the cause of the problem.

Troubleshooting. Table VIII-1 lists the various types of problems that might be encountered in attempting to perform laboratory dyebath reuse experiments at your mill. The potential causes of each type of problem, as well as activities to identify or confirm the specific cause are also presented. Although the remedy is usually obvious and feasible once the cause of the problem is identified, they are listed anyway.

As noted earlier, textile dyeing is a varied and often complicated process. Therefore, although Table VIII-1 contains many problems that could occur in performing reuse dyeings, you may encounter a situation in your experiments for which the problem, cause, remedy, and/or appropriate troubleshooting activity is not presented. In these instances, if you cannot isolate the cause with mill personnel, you should seek outside assistance. A list of experienced dyebath reuse personnel/resources is presented in Appendix G.

TABLE VIII-1

DYEBATH RECONSTITUTION TROUBLESHOOTING CHART

Problem	Possible Causes	Remedy	Appropriate Trouble Shooting Activity
Most dyeings successful, a sporadic few totally unsuccessful.	Occasional technician error in performing a calculation or analysis or procedure.	None. Experience will reduce mistakes.	Review calculations and worksheets for these dyeings (See Note A).
One shade consistently unsuccessful, including first dyeing.	Incorrect dye formulation.	Determine and use correct dye formulation.	Check dye formulation.
One series completely unsuccessful, including first dyeing.	Wrong auxiliary chemicals or amounts or wrong dyestuffs, used in initial bath.	Perform series again using correct auxiliary chemicals and quantities and correct dyestuffs.	Attempt series again.
One series partially unsuccessful with these characteristics: good initial dyeing(s) followed by very poor dyeing, followed by gradually improving dyeings.	Wrong make-up auxiliary chemicals or amounts or wrong dyestuffs used prior to unsuccessful dyeing.	Perform series again.	Attempt series again.
Reuse dyeings unsuccessful for one style, successful for other styles.	Style sensitive to dye strike at elevated temperatures.	Cool dyebath prior to reuse.	Attempt conventional dyeings at elevated temperatures to see if similar problem occurs.
	Other style-specific differences.	Style-specific.	Attempt to isolate difference causing the problem.
Shade matching generally successful for reuse dyeings, however, other features of dyed goods unacceptable.	Mill specific, but definitely not caused by analytical procedures, techniques, or calculations.	Mill-specific.	Mill specific. If difficult to solve at mill, consider using an outside consultant.

TABLE VIII-1 (Continued)

Problem	Possible Causes	Remedy	Appropriate Trouble Shooting Activity
All dyeings, including first dyeings in these reuse series, unsuccessful (See Note B).	Almost anything, but not caused by dyebath reuse since conventional first dyeing also unsuccessful.	Delay reuse experiments until procedures to obtain successful conventional laboratory dyeings are refined.	Attempt to develop a procedure to obtain successful conventional laboratory dyeings.
Dyeings for most or all reuse series become progressively worse with each subsequent bath in a series.	Cumulative buildup of some substance in the dyebath (possibly auxiliary chemicals, tint, or other substance from greige goods, etc.).	Should be identifiable from trouble-shooting activity. Goods may require a prerinse or a different auxiliary chemical make-up amount may be required.	Attempt to identify buildup substance by prerinsing greige goods with cold and/or very hot water. If this does not eliminate problem, experiment with various auxiliary chemical make-up amounts.
Shade matching unacceptable for reuse dyeings of light shades, most shades, or all shades.	(See Note C)		(See Note D)
	Dirty sample cells.	Make sure sample cells are kept scrupulously clean and that there are no visible air bubbles or foreign substances (e.g. fibers) in the sample.	
	Spectrophotometer malfunctioning.	Repair or recalibrate spectrophotometer.	
	Incorrect dye absorbance constant(s)	Develop new dye absorbance constant(s)	
	Calculation procedure in error.	Make necessary corrections to calculation procedures.	
	Interferences present in dyebath sample.	Institute sample preparation procedures to eliminate interferences (See Section V)	

TABLE VIII-1 (Continued)

NOTES

A. Reviewing calculations/worksheets may sometimes identify mistakes. However, many isolated mistakes cannot be caught after the fact - perhaps the wrong make-up dyestuff quantity or auxiliary chemical solution was added unknowingly, the greige goods were improperly weighed, the pH erroneously measured, or any of a multitude of other activities incorrectly performed. These sporadic errors in the laboratory must be expected initially, but they will decrease with time.

B. This problem should only occur at mills that do not already have an established method for performing laboratory dyeings, and are performing them only to test dyebath reuse.

C. Problems of this nature are caused by difficulties with some aspect of dyebath analysis. Within this broad generalization, there are several specific items, any one of which (or possibly something else) may be the cause of this particular problem. It is these specific causes that are listed.

D. To troubleshoot this type of problem sometimes requires creative thinking coupled with observations and a trial and error approach. Often the problem can be isolated through a process of elimination of other causes. For example, dirty sample cells can be eliminated as a cause if distilled water placed in several cells, including one that has never been used, gives the same absorbance reading with each cell to within ±.001. The spectrophotometer can be eliminated as a probable cause, if different concentrations of a single dyestuff in a freshly made dye liquor solution form a relatively linear relationship when concentration is plotted against absorbance at various wavelengths. Likewise, if absorbance constants calculated from the above closely correlate with those obtained earlier (see Section VI), the possibility of incorrect k-values is removed. In a similar manner, experiments can be derived to check the validity of your calculation procedures. The discussion on verifying the validity of dye absorbance constants in Section VI provides some guidance to this approach. If the above items (sample cells, spectrophotometer, k-values, calculation procedure) are cleared as not being the cause of the problem, it is likely that an interference present in the dyebath sample is causing erroneous absorbance readings. Section V presents a discussion of alternative techniques to avoid interferences. Remember that dye absorbance constants must be developed in the same manner (including sample preparation techniques) that your exhausted dyebath analyses are performed.

SECTION IX
FULL-SCALE TRIALS

A distinction should be made at the outset between full-scale trials and full-scale implementation. For the full-scale trials, little effort is made to optimize manpower efficiency. An important feature of these trials is flexibility. Therefore, extra efforts on the parts of mill personnel are traded-off against having to design, purchase, and install permanent arrangements of pipe, pumps, and other fixed or automated equipment.

IMPORTANCE OF FULL-SCALE TRIALS

A principal objective of full-scale trials is to confirm at production level the laboratory success regarding the technical feasibility of dyebath reuse. As noted above, it is important that flexibility be incorporated into these full-scale trials so the various modifications/options/alternatives that you want to examine or consider can be evaluated prior to commitment and investment in permanent equipment.

Additionally, there are limitations to laboratory experiments that full-scale trials overcome. For example, due to the constraints of available laboratory equipment, certain features of the bench- and pilot-scale experiments may have been at variance with full-scale dyeings; examples are procedures for heating (live steam vs. coils), dye and chemical addition, mixing, cooling, and rinsing. Also, certain quality control features of finished products may not be appropriate to evaluate on the basis of laboratory dyeings.

Finally, there is always the possibility of problems developing during full-scale dyeings that cannot be identified in laboratory tests, and thus without full-scale trials the feasibility of dyebath reconstitution and reuse at your mill cannot be determined with absolute certainty. For these reasons, full-scale trials are advisable prior to investment and implementation.

CONDUCTING FULL-SCALE TRIALS

Full-scale trials are to a large extent mill-specific. The actual "set-up" that you use to perform these full-scale trials must be based on the particular situation at your mill. As mentioned in the very first paragraph of this manual, dyebath reuse is not an "off-the-shelf" technology; there is no universal arrangement or piece of equipment that will be appropriate at every mill. Therefore, your mill (and/or consultants) must develop and tailor both these trials and full-scale implementation to your specific conditions. The purpose of this section is to provide guidance and to identify the various aspects that should be considered in planning and performing full-scale trials at your mill.

Preparation

Considerations. A number of factors must be considered in developing the features and procedures of full-scale reuse trials at your mill.

Above all, these full-scale reuse trials should simulate conventional dyeings as closely as possible. The reason for this is to introduce as few variations as possible, other than the feature of reuse, into these trials. Variations, if attempted, should only be performed after successful reuse trials modeled on conventional dyeing procedures have been conducted.

Secondly, these reuse trials should be planned to cause minimal interference with production activities. For example, if spring is the busiest season at your mill, April is obviously a bad month to perform reuse trials as mill personnel will be unable to give as much attention to these experiments. Regardless of when these trials are performed, however, the activities should be designed to minimize disruption and interference with production efforts.

Lastly, in planning these full-scale experiments, activities prior to and during the trials should be incorporated that minimize risks and the opportunity for failure.

Activities. Several activities are necessary in preparation for full-scale reuse trials at your mill. These include: 1) coordination; 2) determining trial scope, schedule, and criteria; 3) developing trial logistics and procedures; 4) acquiring and modifying necessary equipment; and 5) performing dry runs, calibrations, and other efforts necessary to obtain required backup information. These items are each discussed in turn below.

1. Coordination. Coordination and communication are important steps in preparing for full-scale dyebath reuse trials. To assure maximum cooperation and good will, affected personnel (e.g., plant manager, plant engineer, dyehouse superintendent, maintenance supervisor, etc.) should be involved and/or kept aware of plans and preparations for full-scale reuse. In addition, input from appropriate personnel should be sought for activities 2, 3, and 4 below.

2. Determine Trial Scope, Schedule, and Criteria. In this activity, discussions are held to determine how the styles and shades to be dyed in these reuse trials will be selected, how many reuse dyeings will be attempted, when the trials will be performed, and how the quality of reuse dyeings will be evaluated.

The styles, dyes, and auxiliaries used in these trials will be limited to those that have been investigated in laboratory experiments. Unlike the initial laboratory dyeings, however, these series will probably consist of multishade dyeings rather than the same shade dyed repetitively. One possibility for selection is to wait until slightly before the trials are scheduled, and then select shades and styles out of upcoming production requirements; if this alternative for product selection is to be used, affected personnel should be notified of this plan ahead of time. Guidelines for scheduling shades within a series are presented in Appendix D.

The approximate number of reuse series to be performed, as well as the length (i.e., the number of dyeings) planned for each series, should be established ahead of time. The number and length of series chosen should depend on particular conditions at your mill, and whether alternatives are to be evaluated. Generally, however, to assess dyebath reuse feasibility alone, devoid of optimization and alternative evaluations, two to five reuse series consisting of four to ten dyeings each should be sufficient.

The period in which the reuse trials will be performed should be scheduled far enough in advance to allow participants to make necessary preparations. Unless there are extenuating circumstances at your mill, the actual trials themselves should require no more than a two-week period, and generally a week or less. Some "information gathering" activities at the mill may precede this period, but these should cause minimal disruption to regular dyehouse activities. As mentioned previously, if possible the reuse trials should not be scheduled for unusually busy periods.

Criteria for evaluating the success of the reuse dyeings should be established prior to performing the dyeings. A possibility is to treat the resultant dyeings as production goods and process them through subsequent mill activities such as drying, finishing, inspection, etc. in the usual manner; if they pass your quality control "checkpoints," they will be considered successful dyeings. You may also wish to collect a small sample of goods dyed conventionally and those dyed by reuse and compare each group instrumentally against mill standards to see if there are noticeable differences between the groups.

3. Developing Trial Logistics and Procedures. To successfully perform dyebath reuse trials you must have some way to "separate" dyed goods from the exhausted dyebath, while saving the bath and allowing greige goods to be introduced into this reuse bath. If you can remove dyed goods from the dyeing machine (and add greige goods to the dyeing machine) without affecting product quality and with the dyebath in place, then trial logistics should be fairly simple and straightforward. However, circumstances at your mill may dictate that you need to "drain" (i.e., transfer) the exhausted dyebath to remove or add product, or allow for subsequent or preliminary processing (such as rinsing). If you must transfer the dyebath to another (empty) dye machine, or to a holding tank, logistics become more complicated. You must arrange for temporary pumping, hoses or piping, flow measurement, and the like. The particular arrangement you develop will depend on

circumstances unique to your mill, but should incorporate the considerations presented in this section.

As with the laboratory dyeings, the procedures used in these full-scale reuse trials should simulate conventional dyeing as closely as possible. The general guide to procedures presented in Section VIII is modified here to assist you in developing a procedure for reuse trials at your mill.

Step 1. Add volumes/quantities of chemicals, dyes, greige goods, and water in usual sequence, amounts, and proportions for this dyeing (first dyeing in series only).

Step 2. Perform dyeing in your usual manner. For example use the same heating methods, dyeing temperatures, dyebath monitoring and adjustment procedures, and dyeing times as if this were a conventional dyeing.

Step 3. Upon completion of the dyeing either (a) remove the dyed goods from the dye machine or (b) transfer exhausted dyebath to a holding tank or another dye machine for the next dyeing. Rinse, dry, and evaluate dyed product using your usual procedures.

Step 4. Record the exhausted dyebath volume. Collect a small sample of this exhausted dyebath for absorbance measurements. Perform filtration or solvent extraction of this sample if necessary. (See Section V for a description of these sample preparation techniques.)

Step 5. Make absorbance measurements and calculate quantity of dye remaining in exhausted dyebath and amount required for the next dyeing. (See Section V for performance of absorbance measurements, Sections VI and VII for calculation methods.)

Step 6. Add appropriate/calculated amounts of make-up water, greige goods, chemicals, and dyes for next dyeing.

(Repeat Steps 2 through 6 for subsequent dyeings in series.)

4. Acquiring and Modifying Necessary Equipment. Once the logistics for the reuse trials have been determined, necessary equipment for the reuse trials should be assembled at the mill in preparation for

full-scale trials. Analytical equipment, such as a spectrophotometer, calculator/computer, laboratory glassware, etc., should be available from the laboratory trials. Therefore your principal concern will be purchasing, renting, or modifying necessary equipment to enable dyebath transfers (if necessary) to be performed, or to enable related activities to be carried out.

5. Dry Runs, Calibrations, and Backup Information. As noted previously, all activities that reduce uncertainties and eliminate risks relative to the reuse trials should be performed. If exhausted dyebath transfers are required, dry runs to move the dyebaths from and to relevant dye becks should be performed to test and evaluate transfer equipment and procedures. If exhausted dyebath volumes will not otherwise be known during the reuse trials, a flowmeter or known volume calibration of the dye machines should be used for the trials. Any other information that will assist you during these trials should also be obtained ahead of time if possible.

Performance

During the performance of the full-scale trials, personnel associated with the laboratory experiments should be utilized to perform the dyebath analyses and calculations, to monitor the dyeings, and to execute any required dyebath transfers. Forms should be used to record pertinent information for each dyebath in a series. An example of such a form is shown in Appendix C.

All production personnel associated with the dyeings should be made aware that experimental dyeings are being performed so that reuse dyebaths are not accidently drained or diluted, and so that calculated (i.e., make-up) dye and chemical quantities rather than the usual (i.e., recipe) quantities are added to the exhausted dyebaths. Signs on control panels identifying the dyeing as an experiment will assist in reminding personnel of the existence and machine location of a reuse bath. Calculated make-up quantities during the trials should be taken directly to those responsible for measuring dye and chemical additions, so that they are aware each time that the quantities to be added cannot be assumed through force of habit.

Because these full-scale trials are experimental, they will require more attention than conventional dyeings or subsequent reuse dyeings after implementation. For example, extra care should be taken to avoid yarn lot changes during these trials if possible. The pH of the dyebath should be more closely monitored than usual; for example, fiber finish removal during dyeing may change the dyebath pH enough so that adjustment by pH control agents is needed. In addition, you may want to record all additions of auxiliary chemicals during these trials for future reference. Although the computer program discussed in Section VII will maintain a running record of the estimated amount of each chemical in the dyebath at the latest point in time, it does not provide a printed record of all previous chemical additions in the series. You may find such a record useful for analyzing any problems that might develop during the trial series, and for estimating future chemical savings if reuse is implemented.

ASSESSING FULL-SCALE TRIAL RESULTS

The need for developing criteria by which to assess the reuse dyeings was described earlier in this section; alternatives for evaluation were also presented there. Unlike laboratory reuse dyeings, full-scale reuse dyeings should match mill standards or they must be considered unsuccessful.

If your laboratory dyeings have been successful, problems should not develop during these full-scale trials; the point of these full-scale dyeings is to confirm that problems do not exist at the production level. If the unexpected occurs, and problems do unfortunately develop during these experiments, refer to the troubleshooting chart presented previously in Table VIII-1 for assistance in resolving the problem.

SECTION X

FULL-SCALE IMPLEMENTATION

The previously described evaluation of dyebath reconstitution and reuse, based on laboratory and full-scale trials, provides much of the information and criteria needed to implement dyebath reuse at full scale. This section provides guidance on the use of the previously developed information and suggests methods for full-scale implementation. Required activities are listed and discussed, followed by a discussion of additional research and development activities that could be undertaken to further optimize the dyebath reuse scheme at your mill.

REQUIRED ACTIVITIES

Activities considered essential for full-scale implementation include the following:

1. Evaluation of Implementation Criteria, Considerations, and Constraints
    a. Perform economic and technical assessment
    b. Determine portion of mill production initially dedicated to reconstitution; consider expansion of that portion with time
    c. Determine implementation schedule
    d. Determine need for in-house, contractor, and consultant capabilities.
2. Design of Dyebath Reuse System
3. Acquisition and Installation of Reuse System Equipment
4. Training of Dyehouse Personnel

Economic and Technical Assessment

The technical data gathered in the dyebath reuse trials should be reviewed to determine if you will need to make any technical adjustments to your dyeing procedures to implement dyebath reuse. Examples of such adjustments include prerinse of fabric or yarns to remove greige good tints that could affect reuse analyses, and careful control and monitoring of cool down cycles to achieve the proper initial temperature in the dyebath for the next dyeing.

The data gathered in the full-scale trials can also be used to determine the cost-effectiveness of dyebath reuse at your mill. Cost savings, capital costs, and yearly operating/maintenance costs must be estimated, and these can be used to determine the payback period and return-on-investment for dyebath reuse.

Figure X-1 is an example form that can be used to calculate average per cycle savings. The quantity column is based on the savings realized in the full-scale trials. Unit costs for the various items should be readily available from your purchase orders and utility bills. Totals for the various items will show where the bulk of the savings is; generally, the auxiliary chemical savings are the most significant.

The average per cycle savings, as determined above, is essential for completing an economic assessment. By estimating the expected number of dye cycles per year using dyebath reuse, the total annual savings can be projected.

As the full-scale reuse program continues, the economics should be reassessed to compare with your original projections and possibly make adjustments in the program.

Capital costs need to be estimated, and you need to decide if you will do this through in-house or outside expertise. At a minimum, a preliminary piping design and preliminary equipment selection for your system are necessary to develop a reasonable estimate. Included in such a design should be a flow diagram and piping sketch. Design considerations and options are explored in more detail later in this section. An example of a capital cost estimate (for the carpet mill that participated in this study) is presented in Section X of Volume 1.

You must also include in the capital cost estimate the cost for analytical equipment and developmental costs. The cost of analytical equipment already purchased for the testing phase should be added to the cost of any additional analytical equipment required. Table X-1 lists some cost estimates for any equipment you may still need. Developmental costs for the preliminary evaluations and tests that you conducted should be added to the capital cost, since they are a part of the cost of implementing dyebath reuse.

FIGURE X-1

EXAMPLE FORM TO CALCULATE COST SAVINGS

Cost Item	Savings from Reuse		
	Quantity	Unit Cost	Total
Dyes - Yellow			
Red			
Blue			
Other			
Chemicals -			
Water & Sewer (Flow based)			
Sewer Surcharge (BOD)			
(TSS)			
(Other)			
Energy (Steam)			
		Grand Total	

$$\text{Average per cycle savings} = \frac{\text{Grand Total}}{\text{Number of Cycles}}$$

TABLE X-1

CAPITAL COST OF ANALYTICAL EQUIPMENT

Spectrophotometer with Multiple Sample Chamber and Analog Output	$2,600
Analog-to-Digital RS-232C Interface	900
Desk-top Computer with Printer, Keyboard, Display, one Floppy Disc Drive, Operating System, and BASIC Interpreter	3,500
Glassware (Sample cells, Separatory Funnels, Graduated Cylinders, plus Miscellaneous Supplies)	500
Total	$7,500

Operating and maintenance costs are generally broken down to the following areas:

1. Pump system maintenance
2. Laboratory supplies and glassware
3. Electrical power
4. Spectrophotometer/Computer service

Total yearly operating and maintenance costs will generally be about $2,000 per dye machine, but use your actual estimates since conditions and prices will vary from mill to mill.

Figure X-2 is a form that can be used to total the capital costs for implementing dyebath reuse and calculate a simple payback period.

Return-on-investment and cash flow calculations can also be made. Since these include such items as depreciation and income tax, and can be calculated in various ways, you should consult your accounting department to ascertain the accepted method for your company.

Planning Mill Production for Reuse

You must plan the portion of your production that will be done by dyebath reuse. A general guideline is that no more than half of a mill's production will be allocated to reuse dyeing in order to maintain flexibility, but this must be judged according to your production needs. Note that a series of reuse dyeings must generally be planned from light to dark shades, and that economic benefits are generally closer to optimum if the series consists of at least five dyeings. Longer series can be planned to realize greater benefits, in accordance with your economic assessment, but are generally not necessary to have a cost effective dyebath reuse program.

Implementation Schedule

You should develop a schedule for implementation of dyebath reuse, in order to monitor the savings and expenses incurred and make any necessary adjustments in production schedules and methods. A schedule will assist you in planning the overall effort of design, procurement and installation of equipment, training, and execution.

FIGURE X-2

ECONOMIC ANALYSIS

CAPITAL COST SUMMARY	Dollars
Pumping System	$
Analytical Equipment	$
Development Costs	$
Total Capital Costs	$

YEARLY SAVINGS/COSTS	Dollars/Year
Dyes	$
Auxiliary Chemicals	$
Water and Sewer	$
Energy	$
Subtotal	$
Minus Yearly O&M Costs	$
Total Yearly Savings	$

PAYBACK PERIOD CALCULATION
____________ ÷ ____________ = ____________ capital cost   total yearly savings   payback period (years)

In-House vs. Consultant/Contractor Capabilities

You need to consider the capabilities and availability of your mill personnel and determine if these are sufficient to carry out all aspects of implementation. You may concurrently need to research the available consultants and contractors with expertise in this work to determine an appropriate role for such personnel. Your budget and schedule are essential tools for planning how and when the goals of your program will be accomplished.

Design of Dyebath Reuse System

There are several alternative ways to design your system, depending on the physical and production constraints of your mill. Three basic methods can be considered.

- Holding tank - pump system (dyebath transfer)
- Material removal and conventional rinsing in another machine (material transfer)
- Material removal and nonconventional rinsing (material transfer)

Holding Tank - Pump System.

A schematic of a typical system to accommodate two dye machines is provided in Figure X-3. One pump and tank are sufficient for two dye machines, as long as your production is scheduled properly. For three or four dye machines, it is likely that two storage tanks will be needed to accommodate your production schedule. Since pumping generally must be accomplished within about five minutes, one pump with properly operated valves should be sufficient for the dyebath transfer.

A schematic of the three and four machine system is illustrated in Figure X-4. The schematic assumes that the holding tanks are elevated, and that the reuse dyebath can return by gravity within a reasonable time period (five or fewer minutes) to the dye machine.

If physical constraints do not allow for gravity return, then additional piping and valves or a second pump would be needed to pump the reuse dyebath from the storage tank(s) back to the dye machine(s).

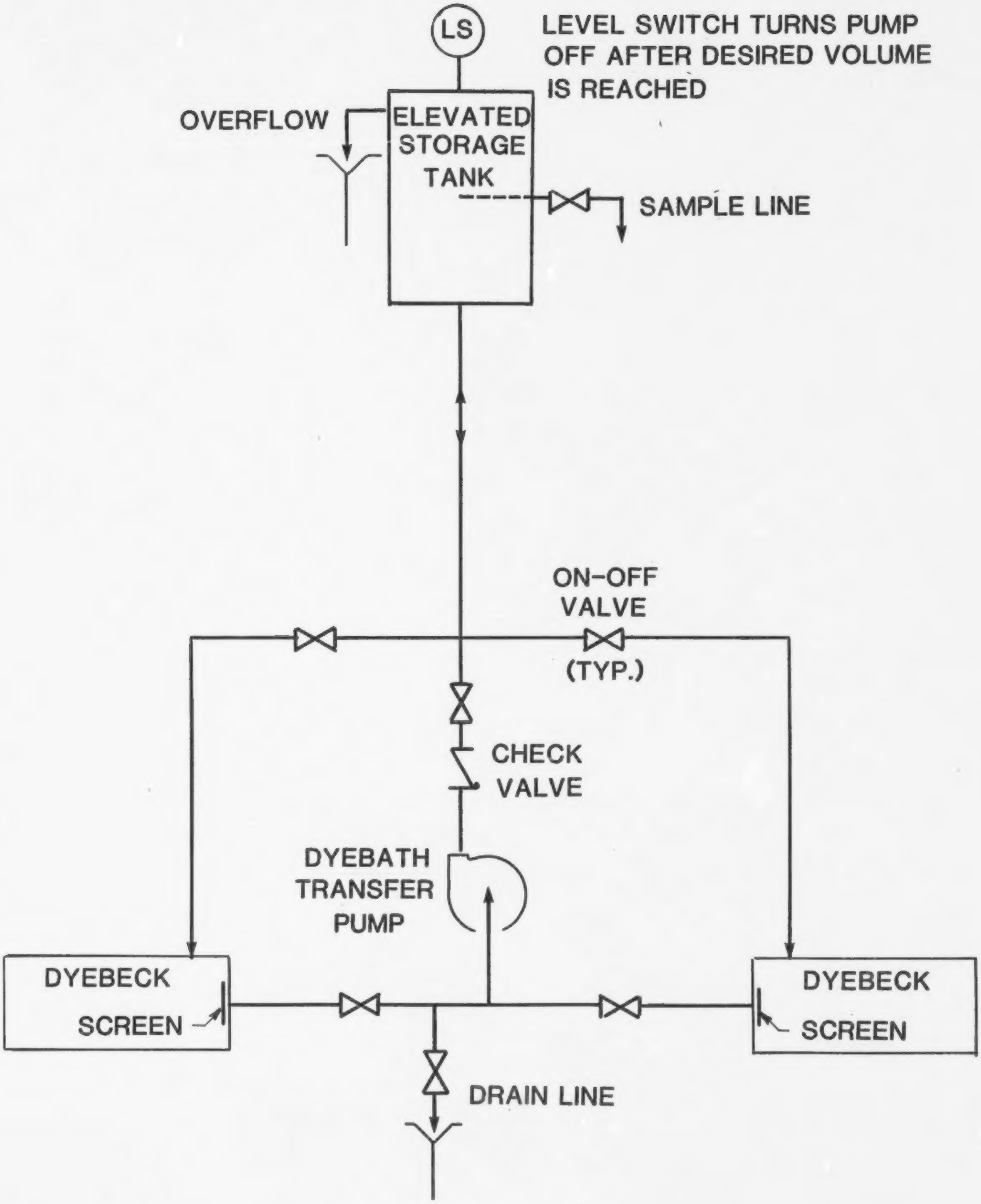

LS
LEVEL SWITCH TURNS PUMP OFF AFTER DESIRED VOLUME IS REACHED
OVERFLOW
ELEVATED STORAGE TANK
SAMPLE LINE
ON-OFF VALVE (TYP.)
CHECK VALVE
DYEBATH TRANSFER PUMP
DYEBECK
SCREEN
DYEBECK
SCREEN
DRAIN LINE

FIGURE X-3
FLOW SCHEMATIC
TWO BECK RECONSTITUTION SYSTEM

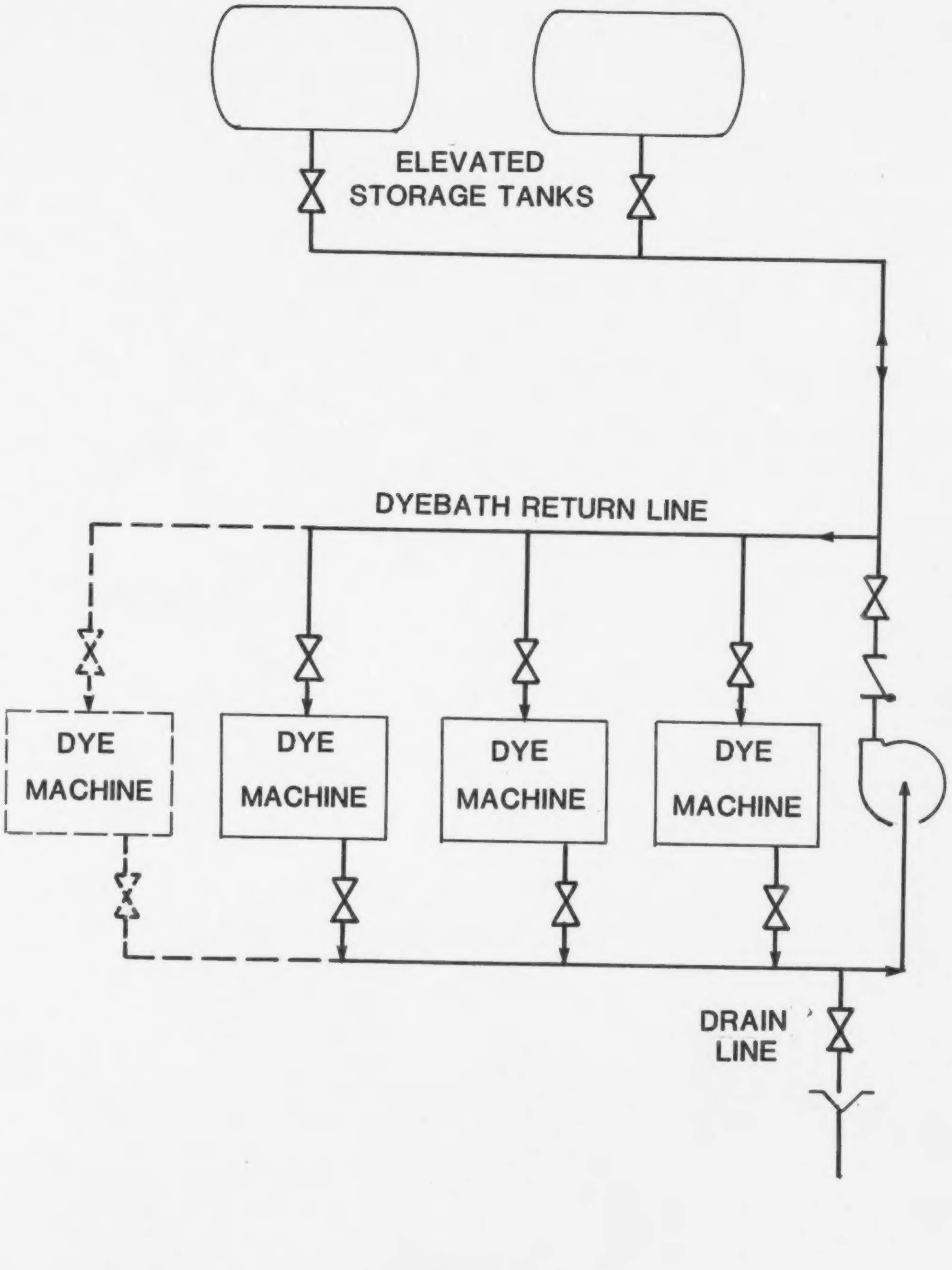

ELEVATED
STORAGE TANKS
DYEBATH RETURN LINE
DYE MACHINE
DYE MACHINE
DYE MACHINE
DYE MACHINE
DRAIN LINE

FIGURE X-4
THREE OR FOUR MACHINE RECONSTITUTION SYSTEM

Material Transfer Methods. You may consider the possibility of moving the dyed material to another dye machine for conventional rinsing, or to another location for nonconventional rinsing. If this is physically and technically feasible in your mill, you would save the cost of designing and installing a pumping system. You may incur some cost in the time needed to transfer the dyed material and possibly in installing material transfer equipment and rinsing equipment.

You may feel that these methods need to be tested thoroughly before full-scale implementation, to assure that "hot pull" of dyed material and alternative rinsing methods will not adversely affect your product. In this case, pilot- and full-scale trials are recommended.

Acquisition and Installation of Reuse System Equipment

During or after the design work, you need to acquire the reuse system equipment. You need to develop an equipment list and identify any items that require a long lead time for purchase. You must consider how you would like to handle the procurement and installation, again considering the capabilities of in-house personnel versus contractors and consultants.

Your mill's procedures for capital improvement projects will be an important factor in the determination of how you elect to acquire and install equipment.

You may opt to have a general contractor handle the procedures mentioned above, in coordination with the design personnel (engineer). If so, you'll likely need to invite several bidders and evaluate their bids before making a selection.

You may also consider the need for subcontractors, using your own people for most of the general or mechanical work, and perhaps hiring a subcontractor for more elaborate electrical controls and instrumentation.

Your decision will be based on the complexity of the system, the degree to which production may be affected during installation, your implementation schedule, and availability of capable personnel.

Training of Dyehouse Personnel

It is essential that you train the chief dyers and their assistants in the techniques needed for dyebath reuse. Some of the training takes place in the laboratory- and full-scale trials, especially with the analytical procedures and computer usage. This training will need to be expanded during full-scale implementation, so that all personnel are aware of the reuse dyeings and learn the alternative procedures that must be followed.

Certain personnel will need to be trained in the operation and maintenance of the pumping system, including controls and instrumentation.

You may want to consider instituting incentives for personnel to learn and conduct the dyebath reuse work, depending on how the reuse system relates to your existing operation. One objective of such training and incentives is to prevent the inadvertent loss of a reuse dyebath, which could happen when personnel have not been indoctrinated to the modified procedures. Careful surveillance is likely to be necessary during the initial few months of reuse, until all personnel are aware of the modification and its effect on their routine procedures.

EXPANDING DYEBATH REUSE CAPABILITIES AND BENEFITS

The required activities discussed above are intended to aid you in study, design, and installation of a basic reuse system, with benefits that are adequate, but perhaps not optimal. There are several additional activities you should plan to help optimize your reuse system. These include additional laboratory experiments, expansion of computer capabilities, and investigation of modifications for your conventional reuse system.

Additional Laboratory Experiments

You should plan efforts on a pilot-scale to identify any problems with increasing the length of your reuse series and with establishing acceptable sequences of shades. Other trials should be planned to identify the optimum temperatures for starting and finishing the dyeings.

Based on the recommendations made earlier in this manual, you have selected perhaps a few dye formulations as suitable for dyebath reuse. Further research should be geared toward developing a greater number of formulations and products that would be suitable for dyebath reuse. For example, attempts should be made to rely on only three dyes in more and more of your formulations, thus enabling the inclusion of these in your reuse system.

Modifications of Conventional Reuse Dyeing

One of the impotant potential modifications is discussed under the discussion of the reuse system design, that is, material transfer as opposed to dyebath transfer. Research may be needed to determine that material transfer, with rinsing done in another dye machine or by other methods, can be accomplished without any adverse effects on production quantity and quality. You may be able to expand your dyebath reuse system with little or no capital expenditure (for pumps and holding tanks) by using the material transfer modification.

In general, you should examine your dyeing procedures for possible reduction of water, energy, and chemical usage. Cooling cycles and liquor ratios should be closely examined and monitored for excessive water use and dilution of valuable chemical content in the dyebath. You should encourage all personnel to be imaginative and creative in making your dyebath reuse system more efficient, as well as your conventional dyeing. In such a highly competitive industry, you cannot afford not to find ways to use resources more efficiently.

GLOSSARY OF DYEBATH REUSE TERMS

DYEBATH ANALYSIS TERMS

Absorbance - A measure of the quantity of light at a given wavelength, or color, absorbed by a medium, e.g., dyebath sample. It is expressed mathematically as log $\frac{P_o}{P}$, where P_o represents the level of radiant power entering the medium, and P represents the radiant power transmitted by the medium. The absorbance is proportional to the concentration of dye in solution. (See Beer's law, Lambert-Beer equation.)

Absorbance Constants (k-values) - Constant of proportionality in the Lambert-Beer equation, relating absorbance to concentration. K-values are determined by plotting absorbance measurements of known concentrations of dye samples against these concentrations and obtaining the slope. These k-values are used in conjunction with absorbance measurements to determine residual dye concentrations by solving sets of simultaneous linear equations.

Absorbance Curve - Plot of absorbance measurements taken at numerous wavelengths in the visible spectrum (380 nm to 700 nm), for a standard dye solution of known concentration. Curves for constitutent dyes in formulations are examined to select the optimum wavelengths for subsequent absorbance measurements of exhausted dyebaths containing these dye combinations.

Beer's Law - Quantitative statement relating absorbance to the concentration of absorbing material in a sample. Formally stated, "Successive increments in the number of identical absorbing molecules in the path of a beam of monochromatic radiation absorb equal fractions of the radiant energy traversing them."[1]

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[1] Ewing, G. W., Instrumental Methods of Chemical Analysis, McGraw-Hill Book Company, 1960, p. 24.

Cuvette - Container used for insertion into sample cell holder in a spectrophotometer. Typically rectangular in shape, it holds a volume of generally less than 10 milliliters of solution. Synonymous with "sample cells."

Lambert-Beer Equation - Mathematical expression of Beer's law to show that absorbance is proportional to the concentration of a particular absorbing substance (dye) in solution. This equation can be written as:

$$A = kC$$

where A = absorbance;
k = constant of proportionality (dye absorbance constant);
C = concentration of absorbing species (dye) in solution.

Mock Dyebath - A solution prepared to measure background absorbance resulting from tints and other impurities in a dyebath. It is prepared by adding all auxiliaries and fabric in proper proportions for a recipe, omitting the dyes, and performing a simulated dyeing at bench scale. This mock dyebath becomes the blank used as a reference standard for comparisons against the absorbance measurements from an actual exhausted dyebath. This mock dyebath is also used to prepare the dye standard solutions used in wavelength selection and k-value development.

Monochromatic Light - Light at one wavelength or color; the resultant light produced by a spectrophotometer through a narrow slit.

Simultaneous Linear Equations - Set of equations, based on the Lambert-Beer equation in this case, that must be solved to calculate residual dye concentrations in exhausted dyebaths. The solution of these equations is a standard mathematical procedure that can be performed by hand calculators with matrix-solution capabilities, or programmed into a desk-top computer.

Solvent Extraction - A procedure sometimes used to prepare exhausted dyebath samples for absorbance measurements. Residual dyes are extracted (transferred) from the dyebath (water) into an organic solvent to obtain separation of the dyes from impurities (such as fiber particles, auxiliary chemicals, fiber finishes, tints, etc.) that could cause interference with absorbance measurements.

Spectrophotometer - Device used for absorbance measurements, consisting of light source, prism or grating, slit constructed to produce monochromatic light, sample compartment, light detector, and electronic circuitry and display. There is a large variety of types available. Minimum specifications are provided in Section V.

Swinny Filter Holder - Small holder for 13-mm membrane filters used for filtration of dyebath samples (as opposed to sample preparation by solvent extraction). Fits onto standard Luer-Lok syringe. Handles a volume of 1 to 5 ml. See Section V of this report.

Wavelength - Term used to differentiate colors. Each color in the spectrum has a particular wavelength associated with it. This wavelength is measured in nanometers (nm) (10^{-9} meters). See monochromatic light, spectrophotometer.

COMPUTER TERMS

Central Processing Unit (CPU) - The core of the computer, which conducts the essential data manipulations and calculations, according to particular programs (software) developed by the computer manufacturer, the user, or others.

Display (CRT Screen) - The screen, similar to a television set, on which input and output of the computer can be viewed. This typical means of displaying the information being entered into or retrieved from the computer is variously referred to as a display, screen, monitor, or CRT (cathode ray tube).

Dyebath Reuse Program - As referred to in this manual, the specific computer program developed during this project to guide the user through the steps of dyebath analysis, ask for essential information about the dye recipes, and provide results of calculations to show the quantities of dyes and auxiliaries needed in the next dyebath. Other dyebath reuse programs can be developed for more or less sophisticated control of dyeings than the specific one listed in Appendix F and used herein.

Floppy Disk Drive - Convenient and rapid means of feeding data and programs to the CPU. The information is contained on small disks (5-1/4 inches is typical size) which can be stored in minimal space. The drive enables rapid processing, as opposed to slower methods such as magnetic tape cassettes. The disks allow for permanent data storage, as opposed to the temporary storage in the random access memory (RAM) of the computer.

Interface (Analog to Digital) - Device used to convert the analog output of a spectrophotometer into a binary (digital) signal that can be interpreted by a computer.

Random Access Memory (RAM); (bytes) - Temporary memory used for storage of programs and data generated during calculations of a particular program. The amount of RAM required, as measured in bytes, depends upon the complexity of the program (software) you desire to use. The RAM of a computer is generally specified by the manufacturer, and is usually expandable with the purchase of additional hardware.

Software - Computer programs developed for the management of the computer and its peripheral devices (keyboard, display, memory, etc.), interpretation of computer languages to machine language, and for manipulation of data and performance of calculations.

OTHER TERMS

Auxiliary Chemicals - Chemicals used to control the conditions of a dyebath such as pH and foam control, to aid in leveling and retarding the dyeing, and to serve other functions such as scouring, softening, chelating, lubricating, wetting, penetrating, etc.

Exhaustion - Term used to express the degree to which dyes and chemicals are taken up by the fibers in a dyebath. Generally expressed in percent.

o.w.f. - Term commonly used to express dye recipes, generally the quantity of dye or auxiliary chemical as a percent of the weight of fiber.

Reconstitution - Specifically, the concept of replacing the exhausted dyes and spent or diluted chemicals in a dyebath, in order for the bath to be reused. As used in this report, reconstitution also refers to the overall process followed for dyebath reuse, including dyebath analysis, replenishment of dyes and chemicals, and reuse of the dyebath.

APPENDIX A

DYEBATH REUSE EVALUATION CHECKLIST AND SUGGESTED PERFORMANCE SCHEDULE

Section IV reviewed the important features of a program to evaluate dyebath reuse at your mill. To assist you in developing such an evaluation program, this appendix lists the major activities that are involved. The format of the following summary enables its use as a checklist and/or a suggested performance schedule.

Upon completion of dyebath reuse evaluation activities, you should develop an implementation schedule, as discussed in Section X, to facilitate full-scale implementation.

EVALUATION ACTIVITIES CHECKLIST AND SCHEDULE

		SCHEDULE		
	ACTIVITY	Typical Manhours Required	Typical Period Required (Days)	Estimated Completion Date
	PRODUCTION SELECTION			
_____	Select Product Styles and Shades	8	1	__________
	LABORATORY PREPARATIONS			
_____	Acquire and Calibrate Spectrophotometer	8	21	__________
_____	Acquire Glassware and Chemicals	8	21	__________
_____	Acquire Calculator or Desk-Top Computer	8	21	__________
_____	Assign Laboratory Personnel	2	1	__________
_____	Prepare Laboratory Space	8	1	__________
_____	Program Computer (if necessary)	40	5	__________
	DYESTUFF ANALYSIS DATA			
_____	Prepare Dye Standards	2	1	__________
_____	Determine Appropriate Concentrations for Known Solutions	2	1	__________
_____	Prepare Solutions of Known Concentration	8	1	__________
_____	Develop Absorbance Curves	16	2	__________
_____	Select Analysis Wavelengths	2	1	__________
_____	Determine k-Values	40	5	__________
_____	Verify k-Values	8	1	__________
	LABORATORY-SCALE TESTS			
_____	Develop Procedures	4	1	__________
_____	Perform Laboratory Reuse Trials	100-350	14-60	__________

EVALUATION ACTIVITIES CHECKLIST AND SCHEDULE (Continued)

		SCHEDULE		
	ACTIVITY	Typical Manhours Required	Typical Period Required (Days)	Estimated Completion Date
	FULL-SCALE TRIALS			
_____	Coordination and Planning	16	*	_____
_____	Develop Trial Logistics and Procedures	40	5	_____
_____	Acquire and Modify Necessary Equipment	100	30	_____
_____	Perform Dry Runs, Calibrations, etc.	24	3	_____
_____	Perform Full-Scale Trials	100-250	5-10	_____

*Coordination and planning activities should take place throughout the dyebath reuse investigation project.

APPENDIX B

ANALYZING YOUR MILL'S DYEBATHS - REFERENCED ACTIVITIES, EXPLANATIONS, AND FORMS

Section VI described the activities necessary to analyze exhausted dyebaths. In order to assist reader comprehension of the "total picture" regarding dyebath analysis, many specific details, examples, and other material that could have been included in that section have been placed instead in this Appendix.

This Appendix is divided into five topic areas as follows:

B1. Preparation of Dye Standard Solutions
B2. Absorbance Curves and Wavelength Selection
B3. Wavelength Selection - A Special Case
B4. Determination of Dye Absorbance Constants
B5. Simultaneous Linear Equations - An Example Solution

Each is referenced in Section VI. Beginning with B1, and continuing through B5, a continuous example is used as part of the discussion to illustrate the material being presented.

B1 - PREPARATION OF DYE STANDARD SOLUTIONS

As noted in Section VI, dye solutions of known concentration are required for certain activities used to determine dyestuff characteristics. The method for preparation of these standard dye solutions is presented below.

For each product style that you have selected for dyeing with dyebath reuse, perform a bench-scale "dyeing" of a small sample of greige goods using the same liquor ratio, auxiliary chemicals, and temperatures used in a full-scale dyeing. However do not add any dyestuffs at this time. Following the "dyeing," take a known volume of the "exhausted dyebath" and add a known quantity of a single dye to this solution. In the same manner, prepare individual standards for other dyes used in formulations for this product style.

You will next need to dilute several portions from each of these dye standards to prepare a range of solutions for each dye. The range of resultant dye concentrations in these solutions should correspond to those that might be expected in exhausted dyebaths. These concentrations can be easily calculated using the following equation:

$$\text{Concentration} = \%\ \text{o.w.f.} \times \frac{(100 - \%\ \text{Typical Exhaustion})}{100} \div \text{Liquor Ratio}$$

By first using the % o.w.f. values found in formulations for the lightest shades in this calculation, and then performing the calculation using the % o.w.f. values for the heaviest shades, the range of concentrations to be developed can be determined. Four or five such solutions of varying concentrations within this range should be sufficient. The laboratory items necessary to perform the above activities are presented below, followed by an example of the complete dye solution preparation process.

The apparatus required for preparing these solutions should be readily available in your laboratory. The items include several beakers and hot plates (or other appropriate means to perform mock dyeings), several (3 or 4) 1-liter volumetric flasks, a dozen 100-ml volumetric flasks, an assortment of 1, 5, and 10-ml pipettes, and several dozen 10-

to 20-ml sample vials to save a portion of the standard dye solutions. In addition, the equipment associated with filtration or solvent extraction, as presented in Section V, will be required for sample preparation prior to making absorbance measurements.

As an example of the preparation of standard dye solutions, suppose that a combination of three dyes - Red Dye #1, Yellow Dye #3, and Blue Dye #1 - are commonly used in the shade formulations for one of the product styles at your mill. You have decided to attempt to reuse the exhausted dyebath from these dyeings and are ready to prepare the dye solutions.

For the sake of this example, we will assume that you usually prepare standard solutions for your laboratory dyeings by measuring 1.000 gms of dry weight dye into a liter of tap water. However, instead of using tap water in the standards for these reuse experiments, you know you need to use "exhausted" dyebaths from "mock" dyeings. Since you need at least three liters of this "mock dyebath" to make one-liter standards for each of the three dyes, plus extra solution for dilution purposes and the spectrophotometer sample cell blanks, you decide to perform sufficient bench-scale dyeings to give you ten liters. So you perform ten "mock" dyeings (i.e., performed in the usual manner, but without dyes) in 1-liter beakers and at the end combine and mix these "exhausted" dyebaths.

Next, measure out exactly 1 liter (1000 ml) of this "dyebath" and add exactly 1.000 grams of Red Dye #1, thus making a one-liter "standard" solution of 0.1% concentration for this dyestuff. You now have to determine the concentrations you need in your diluted samples. Again, for the sake of this example, we will assume that you dye this product with a 10:1 liquor ratio, that your dye formulations range from 0.02% to 2% owf for each dye, and that you reasonably expect in the neighborhood of 95% dye exhaustion. Then, using the equation previously presented:

Lightest Shades

$$\% \text{ Exh. Dye Conc.} = 0.02\% \times \frac{(100-95)}{100} \div 10 = 0.0001\%$$

Darkest Shades

$$\% \text{ Exh. Dye Conc.} = 2.0\% \times \frac{(100-95)}{100} \div 10 = 0.01\%$$

As a result of these calculations, we see that in an exhausted dyebath, dye concentrations for individual dyes will typically range from 0.0001% (0.001 gram dye/liter) to 0.01% (0.1 gram dye/liter). We decide to create 5 separate solutions for Red Dye #1 with concentrations as follows: 0.0001%, 0.0004%, 0.001%, 0.004%, and 0.01%. To do this, take 10 ml of the standard and dilute this to 100 ml using exhausted mock dyebath; this gives a solution with a concentration of .01%. Call this solution "A" and use this solution prepare other solutions in the following manner:

40 ml of Solution "A" diluted to 100 ml with mock dyebath liquor = 0.004% = Solution "B"

10 ml of Solution "A" diluted to 100 ml with mock dyebath liquor = .001% = Solution "C"

4 ml of Solution "A" diluted to 100 ml with mock dyebath liquor = .0004% = Solution "D"

1 ml of Solution "A" diluted to 100 ml with mock dyebath liquor = .0001% = Solution "E"

Repeat the activities outlined above to create a similar set of known solutions for Yellow Dye #3 and Blue Dye #1.

Finally, prepare a sample of each of these dye standard solutions by filtration or solvent extraction and store the prepared samples in sample vials for the next activities.

B2 - ABSORBANCE CURVES AND WAVELENGTH SELECTION

As noted in Section VI, absorbance curves are required to enable selection of the wavelengths to be subsequently used in making absorbance measurements of exhausted dyebaths. Preparation of these absorbance curves, and their use for wavelength selection is discussed below.

An absorbance curve needs to be prepared for each dye in any dye formulations that are planned for inclusion in reuse dyeing series. Preparation of solutions with a range of known concentrations for these dyes has been discussed previously in B1. To develop an absorbance curve for a dye, take one of the previously prepared dye solutions, generally one with a mid-range concentration, and measure its absorbance at every 10 nanometers from 380 nm to 700 nm. (The procedure for performing absorbance measurements is presented in Section V.) Tabulate the results; a form for this purpose is presented as Figure B-1.

Repeat this effort using a sample of the other dyestuffs at this concentration. Then, plot these data on graph paper, and connect the resultant data points to form an absorbance curve for each dye. A blank graph sheet for this purpose is presented as Figure B-2.

Once you have this plot, you are ready to select wavelengths. Again, as noted in Section VI, each of the wavelengths selected should maximize absorbance due to one of the dyes while minimizing absorbance contributions of the other dyes. We will continue with the example used in B1 to illustrate the development of absorbance curves and their use for wavelength selection.

From the activities outlined in B1, we have for each of three dyes - Red Dye #1, Yellow Dye #3, and Blue Dye #1 - a set of solutions of known dye concentration. To obtain data for our absorbance curves, we will use samples for each from Solution "C." These solutions have a dye concentration of 0.001%, a value about mid-range of the expected values in our example.

Measuring the absorbance for each of these samples at every 10 nanometers from 380 nm to 700 nm, we obtain the tabulation presented in

FIGURE B-1

DATA COLLECTION FORM

ABSORBANCE CURVES

DATE ______

READINGS BY ______

STYLE ____________

	DYE 1 ____ ____%	DYE 2 ____ ____%	DYE 3 ____ ____%	DYE 4 ____ ____%
WAVELENGTH (nm)	ABSORBANCE			
380				
390				
400				
410				
420				
430				
440				
450				
460				
470				
480				
490				
500				
510				
520				
530				
540				
550				
560				
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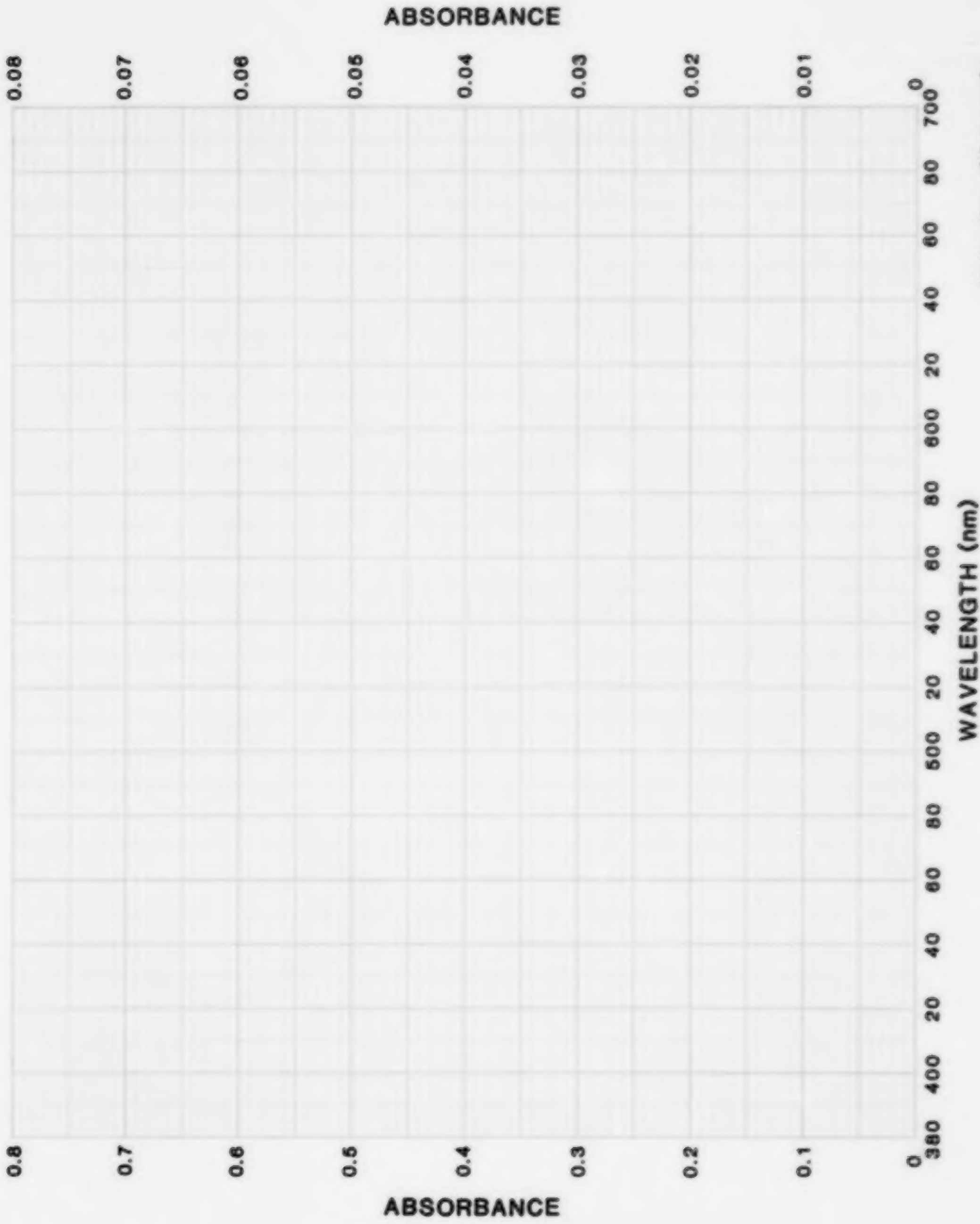
600				
610				
620				
630				
640				
650				
660				
670				
680				
690				
700				



Note: Use either scale
for absorbance

FIGURE B-2

Figure B-3. Plotting these data on a graph results in the set of curves shown in Figure B-4.

In our example, since there are three dyes in the formulations for the dyebaths of interest, we want to select three wavelengths. Examining Figure B-4, it is obvious we want to select one wavelength from each of the following three ranges: 400-440 nm, 520-540 nm, and 600-650 nm. These are the peaks in absorbance for the three dyes. In this case, a wavelength within the first range, say 400 nm, maximizes the absorbance contribution of Yellow Dye #3 while the contributions of Red #1 and Blue #1 are relatively minor. A wavelength within the second range, say 540 nm, maximizes the absorbance contribution of Red Dye #1, while minimizing the contributions of the yellow and blue dyes. A wavelength in the latter range, say 640 nm, gives an absorbance reading almost entirely due to Blue Dye #1, since the absorbance contributions of Red #1 and Yellow #3 are almost insignificant at this wavelength.

Although the selection effort described and illustrated above needs only be performed once for a given dye combination, each combination of dyes that you intend to reuse should be separately evaluated for wavelength selection.

DATA COLLECTION FORM
ABSORBANCE CURVES

DATE 10/24/83
READINGS
BY AOK

STYLE XYZ

	DYE 1 Red #1 .001 %	DYE 2 Yellow #3 .001 %	DYE 3 Blue #1 .001 %	DYE 4 - - %
WAVELENGTH (nm)	ABSORBANCE			
380	.022	.070	.017	
390	.022	.071	.016	
400	.023	.073	.015	
410	.022	.072	.013	
420	.022	.072	.010	
430	.023	.070	.009	
440	.024	.067	.006	
450	.026	.061	.005	
460	.029	.055	.005	
470	.033	.050	.006	
480	.039	.045	.007	
490	.046	.039	.008	
500	.053	.032	.011	
510	.059	.025	.014	
520	.062	.018	.016	
530	.061	.013	.020	
540	.058	.010	.025	
550	.052	.007	.029	
560	.042	.005	.034	
570	.029	.004	.039	
580	.017	.004	.045	
590	.010	.003	.051	
600	.005	.003	.054	
610	.003	.003	.053	
620	.002	.002	.053	
630	.002	.003	.054	
640	.001	.002	.055	
650	.001	.002	.050	
660	.001	.002	.041	
670	.001	.001	.027	
680	.000	.001	.018	
690	.001	.001	.011	
700	.000	.001	.007	

FIGURE B-3 EXAMPLE OF DATA TABULATION FOR WAVELENGTH SELECTION

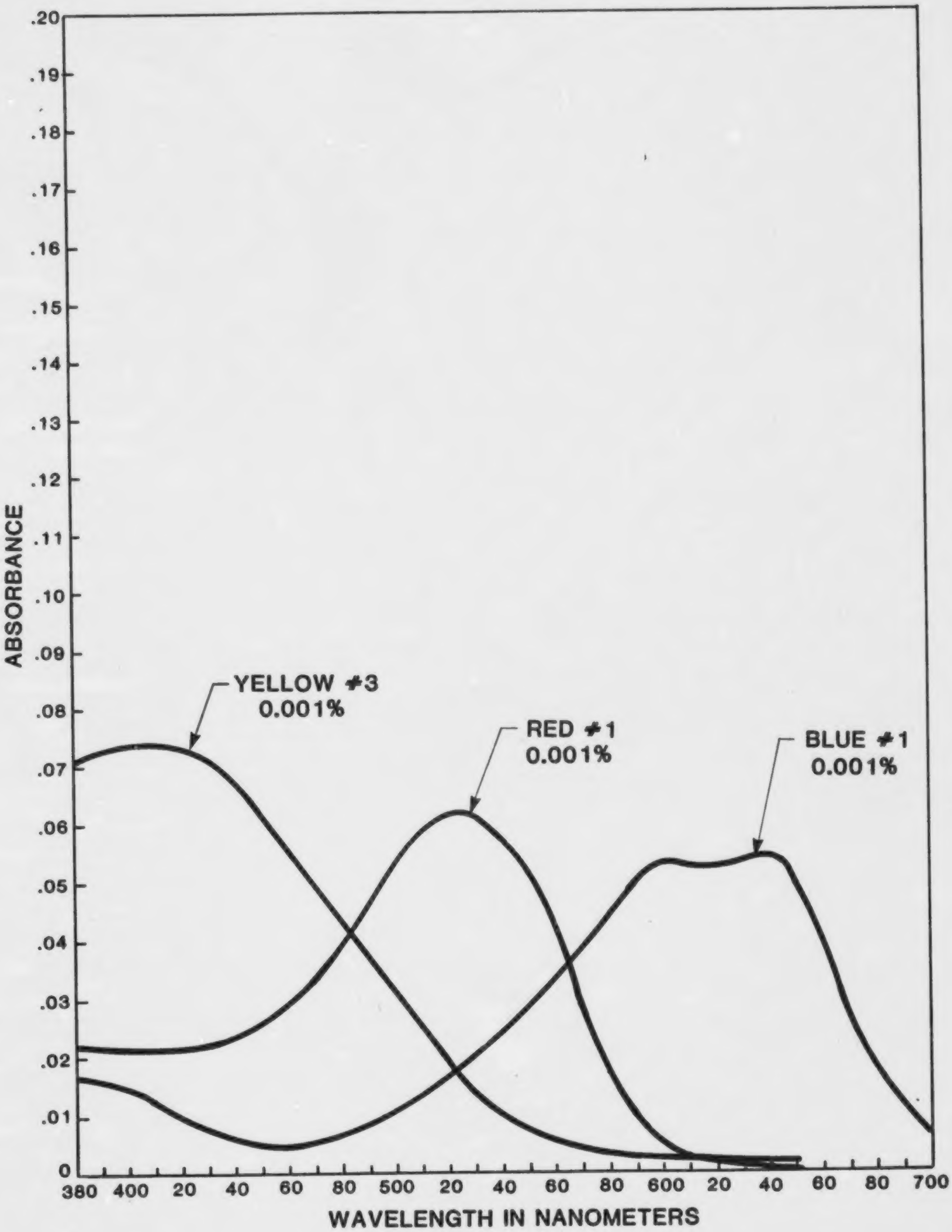


FIGURE B-4
EXAMPLE OF ABSORBANCE CURVES

B3 - WAVELENGTH SELECTION - A SPECIAL CASE

(Residual Color Not Exclusively Attributable to Unexhausted Dyes)

The residual color in the exhausted dyebaths from most dyeing operations is due to unexhausted dyestuffs. However, a few dyehouse operations may experience exhausted dyebaths with some residual color due to other substances. This latter situation can be confirmed by performing a "mock" dyeing without dyestuffs as described in Section V and observing the presence of residual color or stain in the exhaused bath.

If residual color is observed, it obviously will cause significant absorption in the visible region of the spectrum. This in turn will cause difficulties with performing dyebath analyses in the manner described in Section VI. To account for this "non-dye" color or stain, it is treated as an additional "dye" as described below.

A "mock" dyeing is performed and prepared for absorbance measurements in the usual manner. Measurements are recorded every 10 nanometers from 380 nm to 700 nm. Each of the individual dyes is also plotted, as described in B2. The background color is treated as an additional dye, or put another way, the number of wavelengths selected is one more than the number of actual dyestuffs present.

Although absorbance constants for the dyestuffs are calculated in the usual way (see B4), absorbance constants for the background color are calculated in a slightly different manner. A series of ten mock reuse dyeings are preformed in the laboratory as a reconstitution series with the exception that no dyestuffs are added to any of the baths; however, a fresh greige good sample is used for each bath and the previous one removed as if it had been dyed. Since the residual color should gradually build up at a constant rate in the dyebath as the dyeings progress, the concentration in the first bath is arbitrarily referred to as "1," that in the second bath as "2," and so on up to a concentration of "10" in the exhaused dyebath from the 10th mock dyeing in the series.

Using these arbitrary concentrations, and the absorbance measurements for a sample of each bath, an absorbance constant (k-value) for this residual color can be calculated at each wavelength previously selected.

Once the necessary absorbance constants have been determined, residual dye concentrations can be determined as discussed in Section VI. The form of these equations will be as follows:

$$\begin{aligned}
A_{w1} &= k_{w1r}C_r + k_{w1y}C_y + k_{w1b}C_b + k_{w1s}C_s \\
A_{w2} &= k_{w2r}C_r + k_{w2y}C_y + k_{w2b}C_b + k_{w2s}C_s \\
A_{w3} &= k_{w3r}C_r + k_{w3y}C_y + k_{w3b}C_b + k_{w3s}C_s \\
A_{w4} &= k_{w4r}C_r + k_{w4y}C_y + k_{w4b}C_b + k_{w4s}C_s
\end{aligned}$$

In this instance, three dyestuffs in addition to the background color are assumed present in the exhausted bath; "s" refers to stain or other background color, while all other notations are as presented in Section VI. In subsequent reuse dyeings, absorbance measurements will be performed at the selected wavelengths, and concentrations for the dyestuffs and C_s can be calculated. Of course, the resultant concentration for C_s will be relatively meaningless; based on the above procedures, it should correspond closely to the number of dyeings that have been performed in the reuse series to that point.

B4 - DETERMINATION OF DYE ABSORBANCE CONSTANTS

The concept of dye absorbance constants is presented in Section VI. Dye absorbance constants represent the slope of absorbance measurements of individual dyestuff solutions versus the concentrations of these known solutions. These slopes (i.e., dye absorbance constants or k-values) can be determined either mathematically or graphically. Both approaches are discussed below.

To determine k-values mathematically, you can use a desk-top computer; a program to determine k-values in this manner is presented in Appendix F. An example showing the use of this program is given in Figure B-5. Alternatively, you can use a hand-held calculator capable of performing linear-regression; consult your operator's manual to determine how to perform linear regression on these calculators.

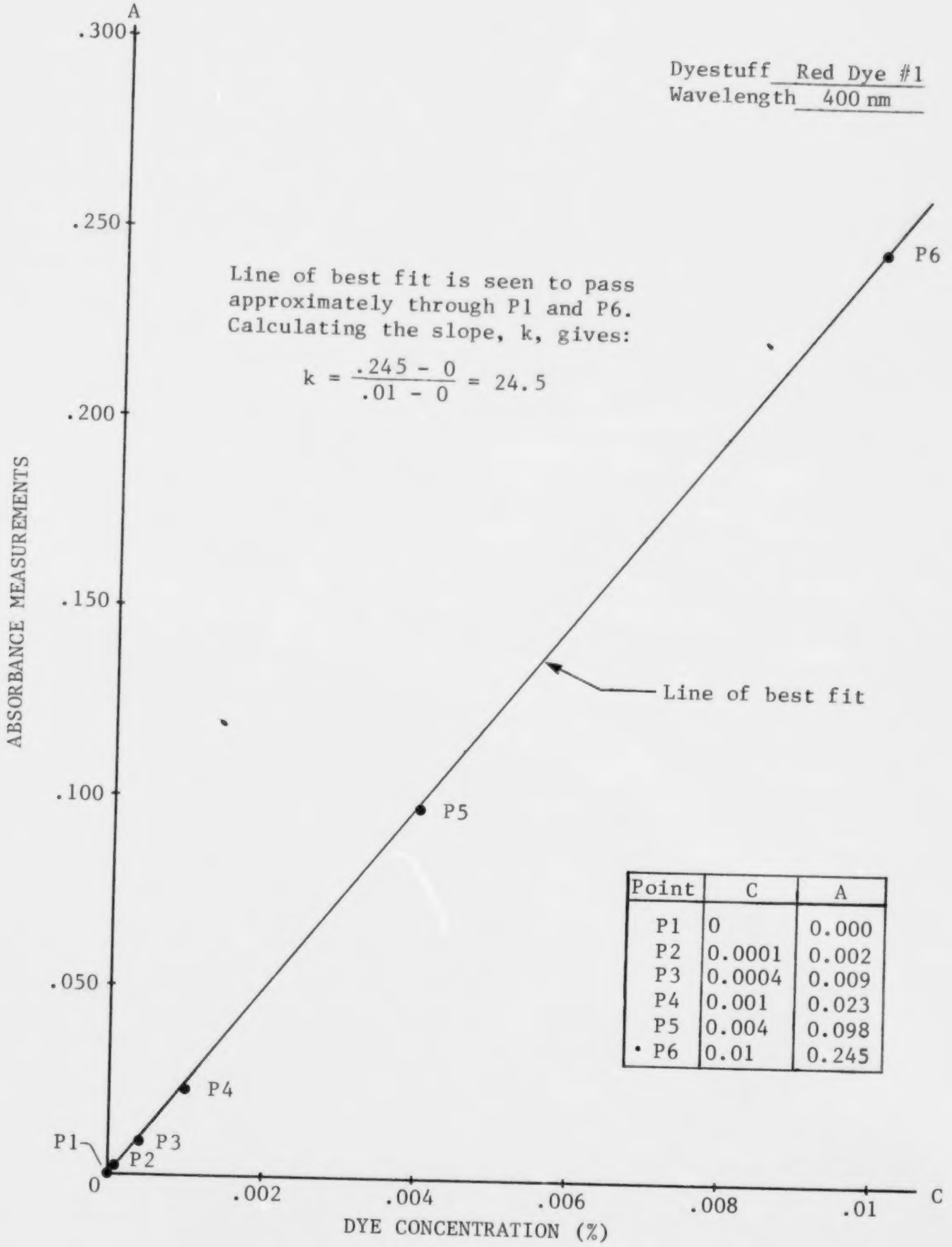
To determine the k-values graphically, plot the data as shown in the example in Figure B-6 and draw a line of best fit through the points; the slope of this line is the k-value for the dye at this wavelength. While this graphical approach makes it easy to visualize the concept of slope, it is more time-consuming than the "electronic" (mathematical) methods described. You will also find that the gradations you need for the absorbance values on your graph paper will vary widely from one k-value to another. An example of k-value development for a system of three dyes follows.

We will again use our assumed combination of Red Dye #1, Yellow Dye #3, and Blue Dye #1. For each of these we will measure the absorbances of each of the previously prepared dye concentrations (.0001%, .0004%, .001%, .004%, and .01%) at each of the previously selected wavelengths (400 nm, 540 nm, and 640 nm). Recording the resultant data results in a tabulation that is summarized in Figure B-7. The calculated k-values (determined by computer) are also shown in this figure for these data.

A form for recording absorbance measurements for a dyestuff at several selected wavelengths to enable subsequent k-value determinations is presented as Figure B-8.

```
THIS PROGRAM COMPUTES DYE ABSORBANCE k-VALUES

TYPE IN DYESTUFF NAME  Red Dye #1
TYPE IN WAVELENGTH (nm)  400
TYPE IN NUMBER OF DATA POINTS  6


FIRST DATA POINT
CONCENTRATION (%)   0
ABSORBANCE READING   0

C = 0.00000      A =0.000    CORRECT <Y or N>?  Y

NEXT DATA POINT
CONCENTRATION (%)   .0001
ABSORBANCE READING   .002

C = 0.00010      A =0.002    CORRECT <Y or N>?  Y

NEXT DATA POINT
CONCENTRATION (%)   .0004
ABSORBANCE READING   .009

C = 0.00040      A =0.009    CORRECT <Y or N>?  Y

NEXT DATA POINT
CONCENTRATION (%)   .001
ABSORBANCE READING   .023

C = 0.00100      A =0.023    CORRECT <Y or N>?  Y

NEXT DATA POINT
CONCENTRATION (%)   .004
ABSORBANCE READING   .098

C = 0.00400      A =0.098    CORRECT <Y or N>?  Y

NEXT DATA POINT
CONCENTRATION (%)   .01
ABSORBANCE READING   .246

C = 0.01000      A =0.246    CORRECT <Y or N>?  Y


THE k-VALUE FOR Red Dye #1 AT 400 nm IS  +24.6
CORRELATION COEFFICIENT IS  +1.00
```

FIGURE B-5   COMPUTER k-VALUE CALCULATION



Dyestuff Red Dye #1
Wavelength 400 nm

Line of best fit is seen to pass approximately through P1 and P6. Calculating the slope, k, gives:

$$k = \frac{.245 - 0}{.01 - 0} = 24.5$$

Point	C	A
P1	0	0.000
P2	0.0001	0.002
P3	0.0004	0.009
P4	0.001	0.023
P5	0.004	0.098
P6	0.01	0.245

FIGURE B-6 EXAMPLE OF GRAPHICAL k-VALUE DETERMINATION

DYESTUFF	RED DYE #1			YELLOW DYE #3			BLUE DYE #1		
WAVELENGTH (nm)	400	540	640	400	540	640	400	540	640
DYE CONCENTRATION %	ABSORBANCE MEASUREMENTS								
0.0001	.002	.005	.000	.008	.001	.000	.001	.003	.006
0.0004	.009	.024	.000	.030	.005	.000	.006	.010	.026
0.001	.023	.058	.001	.073	.010	.002	.015	.025	.055
0.004	.098	.219	.001	.294	.045	.004	.071	.104	.249
0.01	.245	.569	.002	.716	.107	.009	.163	.266	.553
Calculated k-Value*	24.60	56.74	0.18	71.57	10.72	0.89	16.46	26.63	55.50

*Calculated using computer program presented in Appendix F.

FIGURE B-7 EXAMPLE OF DATA TUBALATION FOR K-VALUE DETERMINATIONS

FIGURE B-8

DATA AND CALCULATION FORM
k-VALUES (ABSORBANCE CONSTANTS)

DATE _______
READINGS
BY _________

DYE NAME ____

STYLE ____

Dye Concentration %	Selected Wavelengths*			
	_____ nm	_____ nm	_____ nm	_____ nm
	Absorbance Measurements			
k (Slope)				
Correlation Coefficient (Optional)				

*Columns are provided for up to four selected wavelengths. Use only the first three of these columns if your formulations consist of only three dyes and no interfering substances.

B5 - SIMULTANEOUS LINEAR EQUATIONS - AN EXAMPLE SOLUTION

It is stated in Section VI that once dye absorbance constants have been determined, these values can be used along with absorbance measurements to calculate residual dye concentrations in exhausted dyebaths. The general form of the simultaneous linear equations used to enable these calculations is also presented there; these equations are repeated below:

$$A_{w1} = k_{w1r}C_r + k_{w1y}C_y + k_{w1b}C_b$$
$$A_{w2} = k_{w2r}C_r + k_{w2y}C_y + k_{w2b}C_b$$
$$A_{w3} = k_{w3r}C_r + k_{w3y}C_y + k_{w3b}C_b$$

To solve these equations, you would typically enter the absorbance readings and k-values into a calculator or desk-top computer, and the concentrations of the dyes remaining in the exhausted dyebath would be computed. However, for illustrative purposes only, the steps involved in solving these equations by hand will be presented in the following example. The notation used in this example was defined in Section VI.

Based on previous efforts we have selected analysis wavelengths and determined dye absorbance constants (k-values) for dyebaths containing Red Dye #1, Yellow Dye #3, and Blue Dye #1. Substituting the dye absorbance constants previously developed (see Figure B7) into the general simultaneous linear equations above we get:

$$A_{400} = 24.60\ C_r + 71.57\ C_y + 16.46\ C_b$$
$$A_{540} = 56.74\ C_r + 10.72\ C_y + 26.63\ C_b$$
$$A_{640} = 0.18\ C_r + 0.89\ C_y + 55.50\ C_b$$

This set of equations (with these k-values) will always be used whenever we analyze an exhausted dyebath for this product style containing a combination of only these three dyes. Let's assume that when we measure the absorbances for the first exhausted dyebath we want to analyze, the spectrophotometer shows $A_{400} = .061$, $A_{540} = .048$, and $A_{640} = .019$.

Then,

(Equation 1) $.061 = 24.60\ C_r + 71.57\ C_y + 16.46\ C_b$
(Equation 2) $.048 = 56.74\ C_r + 10.72\ C_y + 26.63\ C_b$
(Equation 3) $.019 = 0.18\ C_r + 0.89\ C_y + 55.50\ C_b$

Rearranging the first equation to isolate C_r gives,

(Equation 4) $C_r = \frac{.061}{24.60} - \frac{71.57}{24.60} C_y - \frac{16.46}{24.60} C_b$, or simplifying,

(Equation 4) $C_r = .00248 - 2.909\ C_y - 0.669\ C_b$

Substituting this result for C_r into Equation 2 gives,

(Equation 5) $.048 = 56.74\ (.00248 - 2.909\ C_y - 0.669\ C_b) + 10.72\ C_y + 26.63\ C_b$, or simplifying

(Equation 5) $.048 = .1407 - 165.06\ C_y - 37.96\ C_b + 10.72\ C_y + 26.63\ C_b$, or simplifying further

(Equation 5) $.048 = .1407 - 154.34\ C_y - 11.33\ C_b$

Rearranging this equation to isolate C_b gives,

(Equation 6) $C_b = - \frac{.048}{11.33} + \frac{.1407}{11.33} - \frac{154.34}{11.33} C_y$, or simplifying,

(Equation 6) $C_b = -.00424 + .01242 - 13.62\ C_y$, or simplifying further,

(Equation 6) $C_b = .00818 - 13.62\ C_y$

Substituting this result for C_b into Equation 3 gives,

(Equation 7) $.019 = .018\ C_r + 0.89\ C_y + 55.50\ (.00818 - 13.62\ C_y)$

We can also substitute Equation 6 into Equation 4 to give,

(Equation 8) $C_r = .00248 - 2.909\ C_y - 0.669\ (.00818 - 13.62\ C_y)$, or simplifying,

(Equation 8) $C_r = .00248 - 2.909\ C_y - .00547 + 9.112\ C_y$, or simplifying further,

(Equation 8) $C_r = -.00299 + 6.203\ C_y$

Substituting this result for C_r into Equation 7 gives,

(Equation 9) $.019 = 0.18\ (-.00299 + 6.203\ C_y) + 0.89\ C_y + 55.50\ (.00818 - 13.62\ C_y)$, or simplifying,

(Equation 9) $.019 = -.000538 + 1.12\ C_y + 0.89\ C_y + .454 - 755.91\ C_y$, or simplifying further,

(Equation 9) $.019 = .453 - 753.9\ C_y$

Rearranging this equation to isolate C_y gives,

(Equation 10) $753.9\ C_y = .453 - .019$, or simplyfing

(Equation 10) $753.9\ C_y = .434$, or

(Equation 10) $C_y = .000576$

Substituting this result for C_y into Equation 6,

(Equation 11) $C_b = .00818 - 13.62\ (.000576)$

(Equation 11) $C_b = .00033$

Substituting the result for Cy into Equation 8 gives,

(Equation 12) $C_r = -.00299 + 6.203\ (.000576)$

(Equation 12) $C_r = .00058$

These concentrations (Red Dye #1 = .00058%; Yellow Dye #3 = .00058%; Blue Dye #1 = .00033%; can then be used in calculations, as described in Section VI, to determine make-up quantities for the next dyeing. First, however, convert these concentrations to units of grams/liter by multiplying by 10.

Or, Red Dye #1 = 0.0058 gram/liter
Yellow Dye #3 = 0.0058 gram/liter
Blue Dye #1 = 0.0033 gram/liter

APPENDIX C

FORM FOR DYEBATH REUSE EXPERIMENTS

The variability of dyeing procedures and features from one mill to the next in the textile industry makes it impossible to develop a data collection form for dyebath reuse experiments that will be universally applicable. Whereas the other forms presented in this manual will serve their purpose with little or no modification, those in this Appendix should be considered to be as much illustrative as functional. In most instances, you will be better served by using the forms presented here as a starting point for developing mill-specific data collection forms of your own for dyebath reuse experiments. The discussion below should assist you in developing your own tailor-made forms, or in using or adapting the forms herein presented.

The principal purpose of a data collection form for these dyeings is to enable you to keep a record of your experimental dyebath reuse series, in addition to aiding in the calculations. The records of these dyeings are also useful in projecting the savings in dyes, chemicals, water, and energy. Specifically, the form assists in recording and monitoring dyebath temperature, pH, and volume, amounts of dyes and chemicals used, and the experimental data and calculations associated with dyebath analysis and reconstitution.

If a desk-top computer is used to perform calculations for dyebath reuse, then certain parts of the data collection form in this Appendix that deal with calculations may not be needed.

For dyebath analysis, space is provided for recording the absorbance (A) measurements at the selected wavelengths; k-values (previously determined) can be entered into the appropriate spots. The dyestuff concentrations (C) in percent by weight that result from solving the equations by hand or computer can also be recorded. These can be converted to concentrations in grams/liter by multiplying by 10. Spaces are also provided for recording the results of dye and chemical make-up calculations.

Again, the form presented in this Appendix is best used as an illustration of the types of data that should be recorded during dyebath reuse experiments. You should develop forms that include other data that you wish to record and that may be more appropriate for the particular circumstances at your mill.

DYEBATH REUSE EXPERIMENT DATA COLLECTION FORM

DATE ____________

REUSE SERIES # ________

BATH # ________

DYE CYCLE MONITORING

	TEMP.	pH	VOLUME
BEGIN DYE CYCLE			
END DYE CYCLE			
END COOLING			
AFTER DYEBATH TRANSFER			

PRODUCT AND RECIPE DATA

	NAME	LAST DYEING	NEXT DYEING	UNITS
STYLE	—			—
SHADE	—			—
WEIGHT	—			
DYE #1				%O.W.F.
DYE #2				%O.W.F.
DYE #3				%O.W.F.
CHEMICAL #1				%O.W.F.
CHEMICAL #2				%O.W.F.
CHEMICAL #3				%O.W.F.
CHEMICAL #4				%O.W.F.

DYEBATH ANALYSIS DATA

WAVELENGTH	ABSORBANCE (A)		K-VALUES				CONCENTRATION	DYE CONCENTRATION
			DYE #1	DYE #2	DYE #3			
nm →							% DYE #1	X 10 = GRAM/LITER
nm →		=				X	% DYE #2	X 10 = GRAM/LITER
nm →							% DYE #3	X 10 = GRAM/LITER

DYE OR AUXILIARY CHEMICAL AMOUNTS

	IN INITIAL BATH	IN ADDS	IN EXHAUSTED BATH	REQUIRED FOR NEXT BATH	MAKE-UP AMOUNT
DYE #1					
DYE #2					
DYE #3					
CHEMICAL #1					
CHEMICAL #2					
CHEMICAL #3					
CHEMICAL #4					

APPENDIX D

GUIDELINES FOR SHADE SEQUENCING IN REUSE BATHS

The description of experimental reuse trials recommended scheduling shades for these series that progress gradually from light to dark. The following test is one approach that can be used to more easily schedule shades in this manner:

Step 1	List all shades with the same combination of dyes and identical auxiliary chemical formulations that are available (i.e., ready) to be dyed, and calculate the total recipe dye weight for each.
Step 2	Arrange these shades in increasing order of the total weight of constituent dyes.
Step 3	Perform the following calculation for each adjacent shade in the list from Step 2: For each dye in the formulation, the weight in the next proposed recipe to be dyed should be greater than 1/6 the weight of the same dye in the previous dyeing.*
Step 4	Shades that pass this test can be scheduled sequentially in a reconstitution series.

The conservative approach of scheduling shades from light to dark is appropriate during experimental trials in order to minimize sources of difficulty. However, greater flexibility is desirable in the scheduling of shades for reconstitution once these reuse dyeings are performed on a regular basis. In most instances reuse dyeings can also progress from darker shades to lighter ones, as well as the other way, as long as the transition is gradual. Under these circumstances, Step 2 above is not applicable. However, Step 3 or a similar check becomes more important.

---

*The basis for this test is found in the following assumptions: The maximum error in determining the residual concentration of each dye is equal to the recipe weight times 5% of dye remaining after exhaustion times 10% maximum analytical error. Or, the maximum error in residual dye amount is 0.5% of the recipe amount. Likewise an error in recipe weight for the next dyeing of less than 3% is generally permissible. This condition will occur if the new recipe dye amounts are greater than 1/6 (or 0.5/3) of the former recipe amounts.

The discussions in this manual have implied that only a single product style can be dyed in a given reconstitution series. This is not necessarily a constraint. In some instances, various styles can be dyed sequentially in a series; the major consideration is that the same combination of dyes be used for each bath in the series, and that the recipe formulation of auxiliary chemicals for each dyeing is identical. Experience and experimentation will show you how much flexibility you have in this regard. It is even possible, particularly if you consistently realize high, i.e., 98 to 100%, exhaustion of dyes, that you can schedule dyeings within a series that do not require the same combination of dyes. However, this approach is not recommended, except at operations obtaining particularly high exhaustion rates, and should definitely not be attempted until a great deal of experience, confidence, and proficiency has been obtained with more traditional dyebath reuse procedures. Generally, a much better alternative for increasing flexibility, discussed previously in this manual, is to reformulate as many recipes as possible to use the same combination of dyes.

A final consideration in the scheduling of shades and styles for reuse dyeings is that this is a task well-suited for a desk-top computer. A program to perform Steps 1 through 4 above could be easily written, or even incorporated into the dyebath reuse program (Appendix F) as a modification. However, in many dyehouses, mill-specific features related to factors such as inventory, lead times, percent of production performed with reuse dyeings, number of dye combinations used, etc. will also affect scheduling. Therefore, each mill should develop a scheduling approach tailored to its situation. If handled correctly, both in terms of attitudes and activities, scheduling should not be an impediment to dyebath reuse.

APPENDIX E

ADDING AND UPDATING REUSE PROGRAM DYE RECIPES

Use of a desk-top computer to facilitate dyebath reuse was discussed in Section VII. The objective there was to describe the features of a computerized dyebath reuse system and illustrate its use in performing reuse dyeings. In order to calculate required make-up quantities for reuse, the computer must access its data storage files for the appropriate dyeing recipes. Thus, adding, listing, and changing dye recipes in the computer's memory are important operations, and are in fact among the first operations performed with this computer program. Dye recipes must be stored prior to using the program for reuse dyeing calculations. This Appendix describes how these operations are performed.

Adding Recipes

When the display shown in Figure E-1 appears, the operator responds "A" and enters the style and shade of the recipe to be added.

You will want to use the form shown in Figure E-2 to prepare the data to be added to the computer. Fill in the form with the information requested and give this form to the computer operator. The computer will ask the operator for each item of information. The operator can obtain the information from this form and type it into the computer. An example is shown in Figures E-3 to E-5. It is important to use the same spelling for dyes and auxiliary chemicals in the various recipes added to the computer.

Once the first recipe is added, the computer will ask the operator if other recipes are to be added in the same group. If so, the computer will assume the same dyes, k-values, and auxiliary chemicals. The operator need only enter the next shade and dyestuff o.w.f. percentages. If the operator responds that no more shades in this group are to be entered, then the display in the top half of Figure E-1 reappears on the screen. To add another group, the procedure is repeated. To add a shade to an existing group, the same procedure is followed.

The computer will review the existing groups for the style to be added, and the operator can then select the appropriate one.

Listing Recipes

Occasionally, you may want a listing of all recipes in the computer's memory. When choosing this option, the information can be listed on the screen or on the printer.

Changing Recipes

When the operator selects this option, the computer first asks which style and shade are to be changed. The operator types in this information and the computer then asks what items are to be changed. If the change is simply in the dyestuff o.w.f. percentages, the computer asks for the changes and stores the revised recipe in its memory.

If, however, a dyestuff name or auxiliary chemical changes, the computer first asks if all shades in this group will experience the same change. If not, the appropriate changes to the one shade are made as the computer asks the operator for information. However, if all shades in the group are to change, the computer first asks for the new dye names, k-values, or auxiliary chemical information, and then automatically reviews each shade in the group and asks the operator for any changes. This is helpful, for example, if a different red dye is now being used for all dyeings in a particular product style. The operator can type in the new dye name and k-values, and review each shade in this group to make any changes in the dyestuff o.w.f. percentages.

```
WHAT DO YOU WANT TO DO?

A.  ADD RECIPE

B.  REVIEW OR CHANGE EXISTING RECIPE

C.  LIST ALL RECIPES

D.  REUSE DYEING OR EXIT

ENTER CHOICE <A to D> A
```

```
INPUT STYLE AND SHADE

 1    STYLE #1
 2    STYLE #2
 3
 4
 5
 6
 7
 8
 9
 10

TYPE NUMBER OF STYLE   1

INPUT SHADE NUMBER   201

STYLE #1  SHADE 201
Correct <Y or N>  Y
```

FIGURE E-1

PRODUCT STYLE ________________

		WAVELENGTHS	nm	nm	nm	nm
	DYESTUFF NAMES (5 Characters)	K-VALUES			
1					
2					
3					
4					

	AUXILIARY CHEMICALS (8 Characters)	lbs or gal	lb/gal	% o.w.f. *
1				
2				
3				
4				
5				
6				
7				

	DYESTUFF % o.w.f. *			
SHADE				

$$* \ \% \text{ o.w.f.} = \frac{\text{WEIGHT OF DYE/AUXILIARY}}{\text{WEIGHT OF PRODUCT}} * 100$$

FIGURE E-2

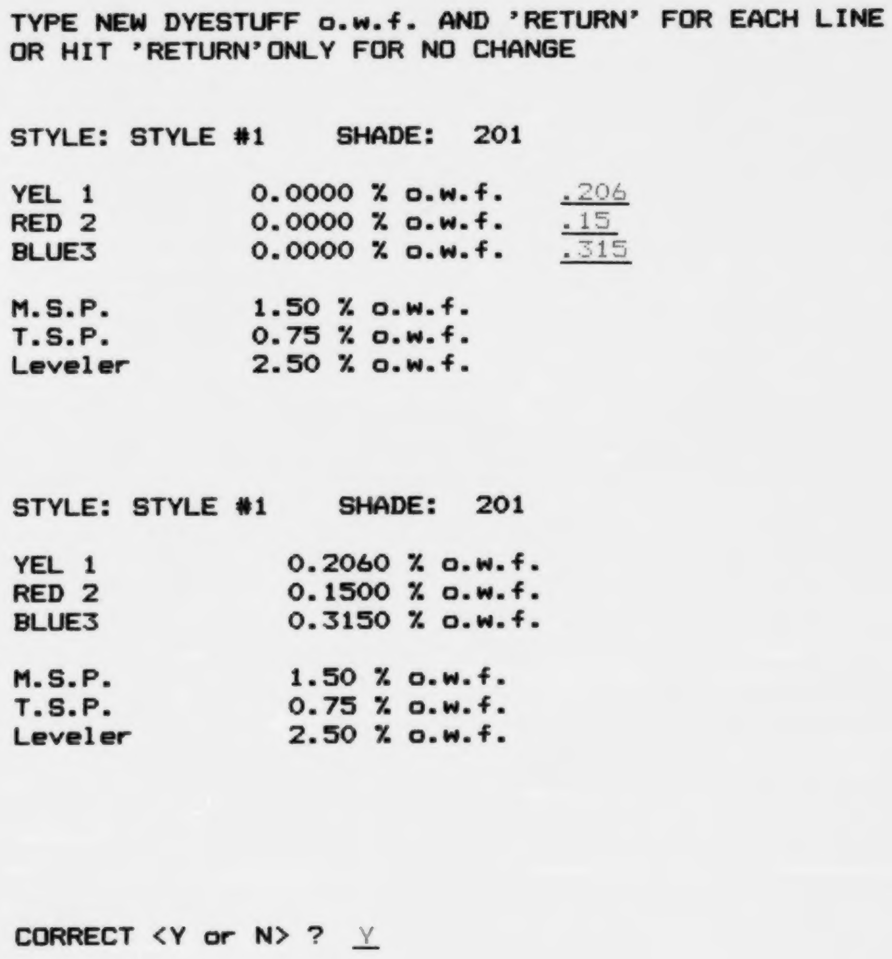
```
INPUT NUMBER OF DYES <1 to 4>  3

DYESTUFF NAME # 1    YEL 1
YEL 1 CORRECT <Y or N>  Y

DYESTUFF NAME # 2    RED 2
RED 2 CORRECT <Y or N>  Y

DYESTUFF NAME # 3    BLUE3
BLUE3 CORRECT <Y or N>  Y


GAMMA # 1  400
 400 nm CORRECT <Y or N>  Y

GAMMA # 2  550
 350 nm CORRECT <Y or N>  Y

GAMMA # 3  650
 650 nm CORRECT <Y or N>  Y




INPUT K-VALUES


WAVELENGTH (nm)           400       550       650

YEL 1                   224.35     26.34      0.00
RED 2                    16.33    109.56      1.25
BLUE3                    35.22     89.35    185.76




WAVELENGTH (nm)           400       550       650

YEL 1                   224.35     26.34      0.00
RED 2                    16.33    109.56      1.25
BLUE3                    35.22     89.35    185.76

CORRECT <Y or N> ?  Y
```

FIGURE E-3

```
TYPE NUMBER OF AUXILIARY CHEMICALS <0 to 7>   3

AUXILIARY # 1  M.S.P.
UNITS <1 for POUNDS, 2 for GALLONS>  1

NAME         UNITS          lb/gal
M.S.P.         lbs                            CORRECT <Y or N> Y

AUXILIARY # 2  T.S.P.
UNITS <1 for POUNDS, 2 for GALLONS>  1

NAME         UNITS          lb/gal
T.S.P.         lbs                            CORRECT <Y or N> Y

AUXILIARY # 3  Leveler
UNITS <1 for POUNDS, 2 for GALLONS>  2
UNIT WEIGHT (lb/gal)  8.3

NAME         UNITS          lb/gal
Leveler        gal             8.3            CORRECT <Y or N> Y
```

```
INPUT % o.w.f.


AUXILIARY     UNITS          % o.w.f.

M.S.P.      lbs             0.00   1.5
T.S.P.      lbs             0.00   .75
Leveler     gal             0.00   2.5


AUXILIARY     UNITS          % o.w.f.

M.S.P.        lbs              1.50
T.S.P.        lbs              0.75
Leveler       gal              2.50

CORRECT <Y or N> ?  Y
```

FIGURE E-4



```
TYPE NEW DYESTUFF o.w.f. AND 'RETURN' FOR EACH LINE
OR HIT 'RETURN'ONLY FOR NO CHANGE

STYLE: STYLE #1    SHADE:  201

YEL 1           0.0000 % o.w.f.    .206
RED 2           0.0000 % o.w.f.    .15
BLUE3           0.0000 % o.w.f.    .315

M.S.P.          1.50 % o.w.f.
T.S.P.          0.75 % o.w.f.
Leveler         2.50 % o.w.f.


STYLE: STYLE #1    SHADE:  201

YEL 1             0.2060 % o.w.f.
RED 2             0.1500 % o.w.f.
BLUE3             0.3150 % o.w.f.

M.S.P.            1.50 % o.w.f.
T.S.P.            0.75 % o.w.f.
Leveler           2.50 % o.w.f.


CORRECT <Y or N> ?  Y
```

FIGURE E-5

APPENDIX F
COMPUTER PROGRAM LISTINGS

Computer program listings are the instructions typed into a computer and recorded on some type of storage device, such as a floppy disk, to enable the computer to perform data processing or other desired activities.

To digress for a moment, computer program listings are referred to as "software," whereas components of the data processing system such as the keyboard, computer, display, printer, and disk drives are referred to as "hardware." A commonly used analogy is to think of software as the brains of the system interpreting information and telling the body, i.e., hardware, what to do. Because of this, a given system of hardware components can be used for an almost infinite variety of applications depending upon the software developed for it.

The software developed during the investigation of dyebath reuse for this project consists of two program listings. The first program is used to calculate dyestuff k-values. In order to determine each k-value or slope, the program determines the line of best fit using the method of least squares. Since the program listing is relatively short, only 40 lines, you may want to type it into the computer and use it to calculate k-values as a means of gaining confidence and experience in using your computer system. The second listing is much more lengthy and contains all elements of the dyebath reuse program discussed in this manual. Specific modifications that may be necessary to use this reuse program with the hardware you purchase are presented in Section VII. Both these program listings are written in and applicable only to computers capable of interpreting MS-BASIC (Microsoft, Inc.); make sure your computer is capable of interpreting this common, although not universal programming language.

Once you have carefully copied the dyebath reuse program listing onto a disk, you should be able to use this program for dyebath reuse as described in Section VII, and for dye recipe storage as described in Appendix E. When you become familiar with the use of this program, you may want to make copies of the program to attempt modifications. For example, you undoubtedly will want to change the heading, and perhaps the format of the output shown in Figure VII-8. Refer to the operating manuals for your computer for programming and editing techniques. Eventually you may even want to develop your own programs for other tasks such as shade sequencing (see Appendix D) or other tasks at your mill unrelated to dyebath reuse.

F1 - PROGRAM LISTING TO CALCULATE DYESTUFF K-VALUES

```
100 REM  COMPUTE K-VALUES
110 DEFINT I,N
120 CLS
130 PRINT "THIS PROGRAM COMPUTES DYE ABSORBANCE k-VALUES"
140 PRINT: PRINT
150 INPUT "TYPE IN DYESTUFF NAME  ", DYENAME$
160 INPUT "TYPE IN WAVELENGTH (nm)  ", WAVELENG
170 INPUT "TYPE IN NUMBER OF DATA POINTS  ", N
180 PRINT: PRINT
190 SUMC = 0!
200 SUMA = 0!
210 SUMC2 = 0!
220 SUMA2 = 0!
230 SUMAC = 0!
240 FOR I = 1 TO N
250 IF I=1 THEN PRINT "FIRST DATA POINT" ELSE PRINT "NEXT DATA POINT"
260 INPUT "CONCENTRATION (%)   ", C
270 INPUT "ABSORBANCE READING  ", A
280 PRINT
290 PRINT "C =";: PRINT USING "##.#####";C;: PRINT "     A =";: PRINT USING "#.###";A;
300 INPUT "   CORRECT <Y or N>  ",Q$
310 IF Q$ = "Y" OR Q$ = "y" THEN 330
320 IF Q$ = "N" OR Q$ = "n" THEN 260 ELSE GOTO 300
330 SUMC = SUMC + C
340 SUMA = SUMA + A
350 SUMC2 = SUMC2 + C*C
360 SUMA2 = SUMA2 + A*A
370 SUMAC = SUMAC + A*C
380 PRINT
390 NEXT I
400 K = (N*SUMAC - SUMA*SUMC)/(N*SUMC2-SUMC*SUMC)
410 CORREL = (N*SUMAC-SUMA*SUMC)/SQR((N*SUMC2-SUMC*SUMC)*(N*SUMA2-SUMA*SUMA))
420 PRINT: PRINT
430 PRINT "THE k-VALUE FOR ";DYENAME$;" AT";WAVELENG;"nm IS";
440 PRINT USING "+####.##";K
450 PRINT "CORRELATION COEFFICIENT IS  ";: PRINT USING "+#.##";CORREL
460 PRINT: PRINT
470 INPUT "ANOTHER? <Y or N>  ",Q$
480 IF Q$="Y" OR Q$="y" THEN CLS: GOTO 140
490 IF Q$="N" OR Q$="n" THEN END ELSE GOTO 470
```

F2 - PROGRAM LISTING FOR DYEBATH REUSE

```
10  REM   DYEBATH REUSE PROGRAM - VERSION 3.0
20  REM   SOURCE LANGUAGE: MS-BASIC (Z-BASIC)
30  REM   WRITTEN:  1983
40  REM   BY:  SVERDRUP & PARCEL AND ASSOCIATES, INC.
50  REM        ST. LOUIS, MISSOURI
60  REM
70  REM   FOR: U.S. ENVIRONMENTAL PROTECTION AGENCY
80  REM        I.E.R.L.  (68-02-3678)
90  REM        RESEARCH TRIANGLE PARK, NC
100 REM
105 ON ERROR GOTO 12030
110 DEFINT F,I,J,L,M,N
120 OPTION BASE 1
130 DIM A(4),C(4),D(4),IROW(4),K(4,4),DYE$(4),GAMMA(4)
140 DIM STYLE$(10),DOWF(4),AUX$(7),AOWF(7),YNDYE(4),YNAUX(7)
150 DIM ODYE$(4),OAUX$(7),OAOWF(7),DLBS(10),AFACTOR(7)
160 DIM EXHAUST(4), ABSOR(4), AUXADD(7), ACON(7), OACON(7), UNIT$(7), OUNIT$(7)
170 FOR I=1 TO 10
180 READ STYLE$(I)
190 NEXT I
200 DATA "STYLE A1","STYLE B2","STYLE C3","STYLE D4","STYLE E5","STYLE F6"
210 DATA "STYLE G7","STYLE H8","STYLE I9","STYLE 10"
220 OPEN "R",#1,"A:RECIPES.DAT",24
230 FIELD #1,2 AS A$,4 AS B$,2 AS C$,4 AS E$,4 AS G$,4 AS I$,4 AS K$
240 OPEN "R",#2,"A:SYSTEMS.DAT",210
250 FIELD #2,2 AS CC$,2 AS NN$,2 AS X3$,5 AS A3$,5 AS B3$,5 AS C3$,5 AS D3$,184 AS X4$
260 FIELD #2,26 AS X5$,8 AS E3$,8 AS F3$,8 AS G3$,8 AS H3$,8 AS I3$,8 AS J3$,8 AS K3$,128 AS X6$
270 FIELD #2,82 AS X7$,2 AS A1$,2 AS B1$,2 AS C1$,2 AS D1$,120 AS X8$
280 FIELD #2,90 AS X9$,4ASA2$,4ASB2$,4ASC2$,4ASD2$,4ASE2$,4ASF2$,4ASG2$,4ASH2$,4ASI2$,4ASJ2$,4ASK2$
    ,4ASL2$,4ASM2$,4ASN2$,4ASO2$,4ASP2$,56 AS X10$
290 FIELD #2,154 AS X11$,4 AS O$,4 AS R$,4 AS T$,4 AS V$,4 AS X$,4 AS Z$,4 AS BB$,4 AS N$,4 AS P$,4
    AS S$,4 AS U$,4 AS W$,4 AS Y$,4 AS AA$
300 GOSUB 4900
310 DLBS(10)=0!
320 CLS
330 PRINT TAB(10) "DYEBATH RECONSTITUTION SYSTEM"
340 PRINT
350 PRINT TAB(20) "VERSION 3.0"
360 PRINT
370 PRINT
380 PRINT
390 PRINT TAB(5) "A.  REUSE DYEING"
400 PRINT
```

```
410 PRINT TAB(5) "B.  UPDATE RECIPES-DATA FILES"
420 PRINT
430 PRINT TAB(5) "C.  EXIT"
440 PRINT
450 PRINT
460 INPUT "ENTER CHOICE <A, B, or C> ";CHOICE$
470 IF CHOICE$ = "A" OR CHOICE$ = "a" THEN 510
480 IF CHOICE$ = "B" OR CHOICE$ = "b" THEN GOSUB 5400: GOTO 320
490 IF CHOICE$ = "C" OR CHOICE$ = "c" THEN 12010
500 GOTO 450
510 REM RECONSTITUTION MONITOR PROGRAM
520 CLS
530 OLDFLAG = 1!
540 PRINT "INPUT LAST STYLE AND SHADE DYED"
550 PRINT
560 FOR I=1 TO 10
570 PRINT I;"   ";STYLE$(I)
580 NEXT I
590 PRINT
600 INPUT "TYPE NUMBER OF STYLE  ",STYLENO%
610 IF STYLENO%<1 OR STYLENO%>10, THEN PRINT "INVALID ENTRY": GOTO 600
620 PRINT
630 PRINT
640 INPUT "INPUT SHADE NUMBER  ",SHADE
650 IF SHADE<1, THEN PRINT "INVALID ENTRY": GOTO 630
660 PRINT
670 PRINT
680 PRINT STYLE$(STYLENO%);"  SHADE";SHADE
690 INPUT "Correct <Y or N>";Q$
700 IF Q$ = "Y" OR Q$ = "y" GOTO 720
710 GOTO 520
720 PRINT: PRINT
730 INPUT "INPUT WEIGHT OF LAST DYEING (Pounds)  ",OWEIGHT
740 IF OWEIGHT<0, THEN PRINT "INVALID ENTRY": GOTO 720
750 PRINT OWEIGHT;"Pounds, ";
760 INPUT "Correct <Y or N>";Q$
770 IF Q$ = "Y" OR Q$ = "y" GOTO 790
780 GOTO 720
790 GOSUB 5100
800 OLDFLAG = 0!
```

```
810 CLS
820 INPUT "INPUT VOLUME OF DYEBATH TO BE REUSED (gallons)  ",VOLUME
830 IF VOLUME<0, THEN PRINT "INVALID ENTRY": GOTO 810
840 PRINT
850 PRINT VOLUME;"Gallons, ";
860 INPUT "Correct <Y or N>";Q$
870 IF Q$ = "Y" OR Q$ = "y" GOTO 890
880 GOTO 810
890 PRINT: PRINT: PRINT
900 INPUT "INPUT TOTAL VOLUME OF EXHAUSTED DYEBATH INCLUDING ANY OVERFLOW LOSSES (Gallons)  ",VOLUME1
910 IF VOLUME1 < VOLUME, THEN PRINT "INVALID ENTRY": GOTO 890
920 PRINT
930 PRINT VOLUME1; "Gallons, Correct <Y or N>";
940 INPUT Q$
950 IF Q$ = "Y" OR Q$ = "y" GOTO 970
960 GOTO 890
970 DFACTOR=1
980 REM  SPECTROPHOTOMETER INPUT ROUTINE
990 FOR I=1 TO N
1000 CLS
1010 PRINT
1020 PRINT "SET WAVELENGTH TO";GAMMA(I);"nm"
1030 PRINT
1040 PRINT "INSERT 'BLANK' CUVETTE AND SET ABSORBANCE AT 0.000"
1050 GOSUB 4300
1060 ABSOR(I)=A(I)
1070 NEXT I
1080 CLS
1090 REM  SOLVE FOR CONCENTRATIONS
1100 GOSUB 3500
1110 PRINT: PRINT "DYE","  CONC %","  EXHAUST %"
1120 PRINT "~~~~~","  ~~~~~~~","  ~~~~~~~~~~"
1130 FOR I=1 TO N
1140 C(I)=C(I)*DFACTOR
1150 IF C(I) < 0, THEN C(I)=0
1160 EXHAUST(I) = 100!*(1-(C(I)*VOLUME1*8.34)/(DOWF(I)*OWEIGHT))
1170 PRINT DYE$(I),C(I),
1180 PRINT USING "#####.#"; EXHAUST(I)
1190 DLBS(I)=C(I)*VOLUME*8.340001E-02
1200 NEXT I
```

```
1210 PRINT
1220 GOSUB 4100
1230 INPUT "HIT 'RETURN' TO CONTINUE",ANY$
1240 CLS
1250 PRINT "INPUT NEXT STYLE AND SHADE"
1260 PRINT
1270 FOR I=1 TO 10
1280 PRINT I;"   ";STYLE$(I)
1290 NEXT I
1300 PRINT
1310 INPUT "TYPE NUMBER OF STYLE  ",STYLENO%
1320 IF STYLENO%<1 OR STYLENO%>10, THEN PRINT "INVALID ENTRY": GOTO 1310
1330 PRINT
1340 PRINT
1350 INPUT "INPUT SHADE NUMBER  ",SHADE
1360 IF SHADE<1, THEN PRINT "INVALID ENTRY": GOTO 1340
1370 PRINT
1380 PRINT
1390 PRINT STYLE$(STYLENO%);"  SHADE";SHADE
1400 INPUT "Correct <Y or N>";Q$
1410 IF Q$ = "Y" OR Q$ = "y" GOTO 1430
1420 GOTO 1240
1430 PRINT: PRINT
1440 INPUT "INPUT WEIGHT OF NEXT DYEING (Pounds)  ",WEIGHT
1450 IF WEIGHT<0, THEN PRINT "ILLEGAL ENTRY": GOTO 1430
1460 PRINT WEIGHT;"Pounds, ";
1470 INPUT "Correct <Y or N>";Q$
1480 IF Q$ = "Y" OR Q$ = "y" GOTO 1500
1490 GOTO 1430
1500 GOSUB 5100
1560 GOSUB 1600
1570 GOSUB 2000
1580 GOTO 320
1590 END
```

```
1600 REM  AUXILIARY CHEMICAL INVENTORY
1610 CLS
1620 PRINT "WERE ANY ADDITIONAL AUXILIARY CHEMICALS ADDED DURING"
1630 INPUT "THE PREVIOUS DYE CYCLE (Chemical Adds) <Y or N>";Q$
1640 IF Q$="Y" OR Q$="y" GOTO 1670
1650 IF Q$="N" OR Q$="n", THEN RETURN
1660 GOTO 1610
1670 CLS
1680 PRINT "INPUT QUANTITIES ADDED"
1690 PRINT
1700 FOR I=1 TO 7
1710 IF OAUX$(I)="        " THEN 1740
1720 PRINT OAUX$(I);" ";OUNIT$(I);
1730 INPUT " ",AUXADD(I)
1740 NEXT I
1750 CLS
1760 PRINT "AUXILIARIES ADDED"
1770 PRINT
1780 FOR I=1 TO 7
1790 IF OAUX$(I)="        " THEN 1810
1800 PRINT OAUX$(I);" ";AUXADD(I);" ";OUNIT$(I)
1810 NEXT I
1820 PRINT
1830 INPUT "Correct <Y or N>";Q$
1840 IF Q$="Y" OR Q$="y" THEN 1860
1850 GOTO 1670
1860 FOR I=1 TO 7
1870 IF OUNIT$(I)="gal", THEN AUXADD(I)=AUXADD(I)*OACON(I)
1880 NEXT I
1890 RETURN
1900 END
```

```
2000 REM  COMPUTE AND PRINT ADD QUANTITIES
2010 GOSUB 3100
2020 PRINT "PRINTING..."
2030 JOBDT$=DATE$
2040 JOBTM$=TIME$
2050 LPRINT TAB(30) CHR$(14) CHR$(27) CHR$(69) "EPA - IERL"
2060 LPRINT TAB(25) CHR$(14) "CARPET MILL C-2"
2070 LPRINT TAB(30) CHR$(27) CHR$(70) CHR$(15) CHR$(27) CHR$(71);
2080 LPRINT CHR$(14) "SVERDRUP & PARCEL"
2090 LPRINT CHR$(18) CHR$(27) CHR$(72)
2100 LPRINT CHR$(10) TAB(70) JOBDT$
2110 LPRINT TAB(71) JOBTM$
2120 LPRINT CHR$(10)
2130 LPRINT CHR$(10) "PRESENT ";
2140 LPRINT "STYLE: " CHR$(27) CHR$(45) CHR$(1) STYLE$(STYLENO%);
2150 LPRINT CHR$(27) CHR$(45) CHR$(0) TAB(35);
2160 LPRINT "SHADE:" CHR$(27) CHR$(45) CHR$(1) SHADE;
2170 LPRINT CHR$(27) CHR$(45) CHR$(0) TAB(53);
2180 LPRINT "WEIGHT: " CHR$(27) CHR$(45) CHR$(1) WEIGHT;
2190 LPRINT CHR$(27) CHR$(45) CHR$(0) "lbs"
2200 LPRINT CHR$(10) "PREVIOUS: " TAB(16) STYLE$(OSTYLE%) TAB(39) OSHD TAB(57)
     OWEIGHT "lbs"
2210 LPRINT CHR$(10) "VOLUME RECYCLED:" VOLUME "GALLONS"
2220 LPRINT CHR$(10) CHR$(10) "ADD QUANTITIES"
2230 LPRINT CHR$(10) CHR$(27) CHR$(45) CHR$(1) "DYESTUFF" TAB(15) "RECYCLE";
2240 LPRINT TAB(26) "RECIPE" TAB(37) "ADD" CHR$(27) CHR$(45) CHR$(0) CHR$(10)
2250 FOR I=1 TO 4
2260 YNDYE(I)=0!
2270 NEXT I
2280 FOR I=1 TO N
2290 NAM$=DYE$(I)
2300 RECLB=DOWF(I)*WEIGHT*.01
2310 FOR J=1 TO N
2320 IF ODYE$(J)=NAM$, THEN FLAG=J: YNDYE(J)=1!: GOTO 2350
2330 NEXT J
2340 FLAG=10
2350 ADDDYE=RECLB-DLBS(FLAG)
2360 IPOUND=FIX(ADDDYE)
2370 ADDOZ=(ADDDYE-IPOUND)*16!
2380 IOUNCE=FIX(ADDOZ)
2390 IGRAIN=FIX((ADDOZ-IOUNCE)*437.5)
2400 LPRINT NAM$ TAB(11);
2410 LPRINT USING "#######.##"; DLBS(FLAG),RECLB;
2420 LPRINT SPC(3) IPOUND "lbs," IOUNCE "oz," IGRAIN "gr";
2430 IF ADDDYE < 0, THEN LPRINT TAB(70) "****";
2440 LPRINT " "
2450 NEXT I
```

```
2460 FOR J=1 TO OLDN%
2470 IF YNDYE(J) > .5 GOTO 2510
2480 LPRINT ODYE$(J) TAB(11);
2490 LPRINT USING "#######.##";DLBS(J);
2500 LPRINT TAB(70) "****"
2510 NEXT J
2520 LPRINT CHR$(10) CHR$(10) CHR$(27) CHR$(45) CHR$(1) "AUXILIARY";
2530 LPRINT TAB(15) "RECYCLE" TAB(26) "RECIPE" TAB(37) "ADD";
2540 LPRINT CHR$(27) CHR$(45) CHR$(0) CHR$(10)
2550 FOR I=1 TO 7
2560 YNAUX(I)=0!
2570 NEXT I
2580 FOR I=1 TO 7
2590 NAM$=AUX$(I)
2600 IF NAM$="        " GOTO 2750
2610 RECLB=AOWF(I)*WEIGHT*.01
2620 FOR J=1 TO 7
2630 IF OAUX$(J)=NAM$, THEN FLAG=J: YNAUX(J)=1!: GOTO 2670
2640 NEXT J
2650 RCYLB=0!
2660 GOTO 2680
2670 RCYLB=(OAOWF(FLAG)*OWEIGHT*.01+AUXADD(FLAG))*AFACTOR(FLAG)
2680 ADDAUX=RECLB-RCYLB
2690 IF UNIT$(I)="gal", THEN ADDAUX=ADDAUX/ACON(I): RECLB=RECLB/ACON(I):RCYLB=RCYLB/ACON(I)
2700 LPRINT NAM$ TAB(11);
2710 LPRINT USING "#######.##";RCYLB,RECLB;ADDAUX;
2720 LPRINT " ";UNIT$(I);
2730 IF ADDAUX < 0, THEN LPRINT TAB(70) "****";
2740 LPRINT " "
2750 NEXT I
2760 FOR J=1 TO 7
2770 IF YNAUX(J) > .5 GOTO 2840
2780 IF OAUX$(J)="        " GOTO 2840
2790 RCYLB=(OAOWF(J)*OWEIGHT*.01 + AUXADD(J))*AFACTOR(J)
2800 IF OUNIT$(J)="gal" THEN RCYLB = RCYLB/OACON(J)
2810 LPRINT OAUX$(J) TAB(11);
2820 LPRINT USING "#######.##";RCYLB;
2830 LPRINT TAB(70) "****"
2840 NEXT J
2850 GOSUB 2900
2860 LPRINT CHR$(140)
2870 RETURN
2880 END
```

```
2900 REM PRINT EXPERIMENTAL DATA
2910 LPRINT CHR$(10) CHR$(10) TAB(32) CHR$(27) CHR$(45) CHR$(1);
2920 LPRINT "EXPERIMENTAL DATA" CHR$(27) CHR$(45) CHR$(0)
2930 LPRINT CHR$(10) "WAVELENGTH" TAB(15) "ABSORBANCE" TAB(40) "DYESTUFF";
2940 LPRINT TAB(53) "CONCENTRATION %" TAB(72) "EXHAUST %"
2950 LPRINT
2960 FOR I=1 TO N
2970 LPRINT TAB(3) GAMMA(I) TAB(18);
2980 LPRINT USING "##.###";ABSOR(I);
2990 LPRINT TAB(41) ODYE$(I) TAB(53) C(I) TAB(73);
3000 LPRINT USING "###.##";EXHAUST(I)
3010 NEXT I
3020 RETURN
3030 END
```

```
3100 REM  AUXILIARY LOSS CALCULATIONS
3110 CLS
3112 ALOSS = VOLUME/VOLUME1
3115 LOSS = CINT(100*(1!-ALOSS))
3120 PRINT "THE SYSTEM WILL ASSUME A"; LOSS; "% LOSS FOR ALL AUXILIARIES."
3130 PRINT "DO YOU WISH TO CHANGE THIS TO A DIFFERENT LOSS PERCENTAGE <Y or N>";
3140 INPUT Q$
3150 IF Q$ = "N" OR Q$ = "n", THEN ALOSS = 1!-LOSS/100!: GOTO 3240
3160 PRINT
3170 INPUT "TYPE NEW LOSS PERCENTAGE <0 to 100>  ", ANLOSS
3180 IF ANLOSS > 100 OR ANLOSS < 0, THEN PRINT "INVALID ENTRY": GOTO 3160
3190 PRINT
3200 PRINT ANLOSS "PERCENT <Y or N>";
3210 INPUT Q$
3220 IF Q$ = "Y" OR Q$ = "y", THEN ALOSS = 1!-ANLOSS/100!: GOTO 3240
3230 GOTO 3110
3240 FOR I=1 TO 7
3250 AFACTOR(I) = ALOSS
3260 NEXT I
3270 CLS
3280 PRINT "THE SYSTEM WILL ASSUME THE FOLLOWING LOSSES FOR THE"
3290 PRINT "AUXILIARY CHEMICALS IN THE LAST DYEBATH:"
3300 PRINT
3310 FOR I=1 TO 7
3320 IF DAUX$(I)="        " THEN 3350
3330 PRINT I DAUX$(I);"  ";
3340 PRINT USING "###.#"; (1 - AFACTOR(I))*100;: PRINT "%"
3350 NEXT I
3360 PRINT
3370 PRINT "TO MAKE ANY CHANGES, TYPE NUMBER OF AUXILIARY CHEMICAL"
3380 PRINT "HIT RETURN TO CONTINUE"
3390 INPUT S6%
3400 IF S6% > 7 OR S6% < 0, THEN PRINT "INVALID ENTRY": GOTO 3370
3410 IF S6% = 0 GOTO 3460
3420 INPUT "TYPE NEW LOSS PERCENTAGE <0 to 100>  ", S7
3430 IF S7<0 OR S7>100, THEN PRINT "INVALID ENTRY": GOTO 3420
3440 AFACTOR(S6%)=1! - (S7/100!)
3450 GOTO 3270
3460 RETURN
3470 END
```

```
3500 REM  SOLVE N x N MATRIX
3510 FOR I= 1 TO N
3520 IROW(I)=I
3530 D(I)=0!
3540 FOR J=1 TO N
3550 IF D(I)>=ABS(K(I,J)) THEN 3570
3560 D(I)=ABS(K(I,J))
3570 NEXT J
3580 NEXT I
3590 NM=N-1
3600 FOR IDIAG=1 TO NM
3610 L=IDIAG+1
3620 ID=IROW(IDIAG)
3630 BIG=ABS(K(ID,IDIAG))/D(ID)
3640 IBIG=IDIAG
3650 FOR I=L TO N
3660 IR=IROW(I)
3670 T=ABS(K(IR,IDIAG))/D(IR)
3680 IF BIG>=T THEN 3710
3690 BIG=T
3700 IBIG=I
3710 NEXT I
3720 IF IBIG=IDIAG THEN 3750
3730 IROW(IDIAG)=IROW(IBIG)
3740 IROW(IBIG)=ID
3750 ID=IROW(IDIAG)
3760 FOR I=L TO N
3770 IR=IROW(I)
3780 T=K(IR,IDIAG)/K(ID,IDIAG)
3790 K(IR,IDIAG)=T
3800 FOR J=L TO N
3810 K(IR,J)=K(IR,J)-K(ID,J)*T
3820 NEXT J
3830 A(IR)=A(IR)-A(ID)*K(IR,IDIAG)
3840 NEXT I
3850 NEXT IDIAG
3860 K%=IROW(N)
3870 C(N)=A(K%)/K(K%,N)
3880 M=N-1
3890 L=N
3900 FOR J=1 TO M
3910 SUM=0!
3920 K%=IROW(L-1)
3930 FOR I=L TO N
3940 SUM=SUM+(K(K%,I))*C(I)
3950 NEXT I
3960 L=L-1
3970 C(L)=(A(K%)-SUM)/K(K%,L)
3980 NEXT J
3990 RETURN
4000 END
```

```
4100 REM  SAVE PREVIOUS STYLE/SHADE DATA
4110 OSTYLE%=STY%
4120 OSHD=SHD
4130 FOR I=1 TO N
4140 ODYE$(I) = DYE$(I)
4150 NEXT I
4160 FOR I=1 TO 7
4170 OAUX$(I) = AUX$(I)
4180 OAOWF(I) = AOWF(I)
4190 OUNIT$(I)=UNIT$(I)
4200 OACON(I)=ACON(I)
4210 NEXT I
4220 OLDN% = N
4230 OLDSYS%=SYSNO%
4240 RETURN
4250 END
```

```
4300 REM   DATA INPUT FROM SPEC-21
4310 BEEP
4320 INPUT "HIT 'RETURN' WHEN READY TO CONTINUE",ANY$
4330 IF LOC(3)=0 THEN 4350
4340 VOID$=INPUT$(LOC(3),#3)
4350 PRINT #3,"BCD.5"
4360 WHILE LOC(3)<62
4370 WEND
4380 PRINT #3,CHR$(0)
4390 INPUT #3,VOID$,VOID1$,VOID2$,VOID3$,VOID4$,VOID5$,VOID6$,IZERO
4400 IF IZERO=0 THEN 4780
4410 PRINT
4420 PRINT
4430 BEEP
4440 PRINT "INSERT SAMPLE CUVETTE"
4450 INPUT "HIT 'RETURN' WHEN READY",ANY$
4460 IF LOC(3)=0 THEN 4480
4470 VOID$=INPUT$(LOC(3),#3)
4480 PRINT #3,"BCD.5"
4490 WHILE LOC(3)<62
4500 WEND
4510 PRINT #3,CHR$(0)
4520 INPUT #3,VOID$,VOID1$,VOID2$,VOID3$,VOID4$,VOID5$,VOID6$,ITRN
4530 TRANS=ITRN*100!/IZERO
4540 IF TRANS=0, THEN 4780
4550 A(I)=2!-(LOG(TRANS))/2.3026
4560 IF A(I)<0!,THEN A(I)=0!
4570 PRINT
4580 PRINT
4590 PRINT "ABSORBANCE AT"; GAMMA(I); " nm = ";
4600 PRINT USING "#.###"; A(I)
4610 INPUT "Correct <Y or N>";Q$
4620 IF Q$="Y" OR Q$="y" THEN 4640
4630 INPUT "INPUT ABSORBANCE  ",A(I)
4640 IF A(I)>1.2 THEN 4700
4650 RETURN
4660 END
```

*** SEE NEXT PAGE FOR NO-INTERFACE ALTERNATE ***

```
*** NO-INTERFACE ALTERNATE ***


4300 REM   DATA INPUT FROM SPEC-21
4310 BEEP
4320 INPUT "HIT 'RETURN' WHEN READY TO CONTINUE",ANY$
4410 PRINT
4420 PRINT
4430 BEEP
4440 PRINT "INSERT SAMPLE CUVETTE"
4450 INPUT "TYPE IN ABSORBANCE AND HIT 'RETURN'  ",A(I)
4570 PRINT
4580 PRINT
4590 PRINT "ABSORBANCE AT"; GAMMA(I); " nm = ";
4600 PRINT USING "#.###"; A(I)
4610 INPUT "Correct (Y or N)";Q$
4620 IF Q$="Y" OR Q$="y" THEN 4640
4630 GOTO 4450
4640 IF A(I)>1.2 THEN 4700
4650 RETURN
4660 END




4700 REM  DILUTION ROUTINE
4710 PRINT
4720 BEEP
4730 PRINT "ABSORBANCE IS TOO HIGH"
4740 PRINT "DILUTE 1 PART SAMPLE WITH 1 PART BLANK LIQUOR (or solvent)"
4750 DFACTOR = DFACTOR*2!
4760 INPUT "HIT 'RETURN' WHEN READY TO CONTINUE",ANY$
4770 GOTO 980
4780 PRINT "---DATA READ ERROR---"
4790 PRINT "CHECK SPECTROPHOTOMETER AND/OR INTERFACE"
4800 GOTO 12030
4810 END
```

```
4900 REM  INTERFACE SET-UP ROUTINE
4910 CLS
4920 BEEP
4930 PRINT "SET INTERFACE 'ON/OFF' POWER SWITCH TO 'ON'"
4940 INPUT "HIT 'RETURN' WHEN READY TO CONTINUE",ANY$
4950 OPEN "COM1:1200,E,7,2" AS #3
4960 PRINT #3,"RANGE1 4"
4970 PRINT #3,"RANGE2 4"
4980 IF LOC(3)<>0 THEN 5000
4990 RETURN
5000 SPEC$=INPUT$(LOC(3),#3)
5010 PRINT SPEC$;
5020 GOTO 4980
5030 END
```

```
*** NO-INTERFACE ALTERNATE ***
```

```
4900 REM  INTERFACE SET-UP ROUTINE
4910 CLS
4990 RETURN
5030 END
```

```
5100 REM  READ RECIPE AND SYSTEM FILES
5110 PRINT "SEARCHING FILES..."
5120 I=1
5130 GET #1,I
5140 IF EOF(1) THEN 5320
5150 STY%=CVI(A$)
5160 IF STY%=STYLENO% THEN 5190
5170 I=I+1
5180 GOTO 5130
5190 SHD=CVS(B$)
5200 IF ABS(SHD-SHADE)<.001 THEN 5230
5210 I=I+1
5220 GOTO 5130
5230 GOSUB 11200
5240 IF OLDFLAG < .5 AND OLDSYS%=SYSNO%, THEN RETURN
5250 GET #2,SYSNO%
5260 IF EOF(2) THEN 5350
5270 GOSUB 11300
5280 IF OLDFLAG < .5, THEN RETURN
5290 GOSUB 11700
5300 RETURN
5310 REM  ERROR RETURNS
5320 PRINT "CAN'T FIND STYLE/SHADE"
5330 INPUT "HIT 'RETURN' TO START OVER ",ANY$
5340 RETURN 320
5350 PRINT "CAN'T FIND SYSTEM"
5360 INPUT "HIT 'RETURN' TO START OVER ",ANY$
5370 RETURN 320
5380 END
```

```
5400 REM  EDIT RECIPE FILE
5410 CLS
5420 PRINT "WHAT DO YOU WANT TO DO?"
5430 PRINT
5440 PRINT "A.  ADD RECIPE"
5450 PRINT
5460 PRINT "B.  REVIEW OR CHANGE EXISTING RECIPE"
5470 PRINT
5480 PRINT "C.  LIST ALL RECIPES"
5490 PRINT
5500 PRINT "D.  REUSE DYEING OR EXIT"
5510 PRINT
5520 PRINT "ENTER CHOICE <A to D>";
5530 INPUT CHOICE$
5540 IF CHOICE$="A" OR CHOICE$="a", THEN GOSUB 5600: GOTO 5410
5550 IF CHOICE$="B" OR CHOICE$="b", THEN GOSUB 6000: GOTO 5410
5560 IF CHOICE$="C" OR CHOICE$="c", THEN GOSUB 10800: GOTO 5410
5570 IF CHOICE$="D" OR CHOICE$="d", THEN RETURN
5580 GOTO 5520
5590 END
```

```
5600 REM  ADD RECIPE
5610 GOSUB 6800
5620 IRECNO=0
5630 GOSUB 7100
5640 IF IRECNO>0, THEN PRINT "RECIPE ALREADY EXISTS": INPUT "HIT 'RETURN' TO CONTINUE",ANY$: RETURN
5650 IRECNO=ILASTREC
5660 GOSUB 8300
5670 FOR I=1 TO 4
5680 DOWF(I)=0!
5690 NEXT I
5700 GOSUB 8100
5710 GOSUB 6600
5720 CLS
5730 PRINT "DO YOU WISH TC ADD ANY MORE RECIPES OF THIS STYLE"
5740 INPUT "USING THE SAME DYE SYSTEM <Y or N>";Q$
5750 IF Q$="Y" OR Q$="y" THEN 5770
5760 RETURN
5770 INPUT "NEXT SHADE NUMBER  ",SHADE
5780 IF SHADE < 1, THEN PRINT "INVALID ENTRY": GOTO 5720
5790 PRINT
5800 PRINT
5810 PRINT STYLE$(STYLENO%);"  SHADE";SHADE
5820 PRINT "Correct <Y or N> ";
5830 INPUT Q$
5840 IF Q$="Y" OR Q$="y" THEN 5860
5850 GOTO 5720
5860 IRECNO=0
5870 GOSUB 7100
5880 IF IRECNO>0, THEN PRINT "RECIPE ALREADY EXISTS": INPUT "HIT 'RETURN' TO CONTINUE",ANY$: RETURN
5890 IRECNO=ILASTREC
5900 GOTO 5670
5910 END
```

```
6000 REM  REVIEW OR CHANGE RECIPE
6010 GOSUB 6800
6020 IRECNO=0
6030 GOSUB 7100
6040 IF IRECNO=0, THEN PRINT "RECIPE NOT FOUND": INPUT "HIT 'RETURN' TO CONTINUE",ANY$: RETURN
6050 GOSUB 11200
6060 GET #2,SYSNO%
6070 IF EOF(2) THEN 6530
6080 GOSUB 11300
6090 GOSUB 11700
6100 GOSUB 8100
6110 LOCATE 18,1,1
6120 INPUT "DO ANY DYE NAMES OR AUXILIARY NAMES CHANGE <Y or N> ";Q$
6130 IF Q$="Y" OR Q$="y", THEN GOSUB 9500: GOTO 6160
6140 INPUT "DO AUXILIARY CHEMICAL WEIGHTS CHANGE <Y or N> ";Q$
6150 IF Q$="Y" OR Q$="y", THEN GOSUB 9500
6160 GOSUB 8100
6170 LOCATE 22,1,1
6180 INPUT "DO DYE WEIGHTS CHANGE <Y or N> ";Q$
6190 IF Q$="Y" OR Q$="y", THEN 6210
6200 GOSUB 6710: GOTO 6230
6210 GOSUB 6600
6230 INPUT "SHOULD ALL OTHER SHADES IN THIS SYSTEM BE REVIEWED FOR CHANGES ";Q$
6240 IF Q$="Y" OR Q$="y" THEN 6260
6250 RETURN
6260 IC=1
6270 GET #1,IC
6280 IF EOF(1) THEN RETURN
6285 SHADE = CVS(B$)
6290 GOSUB 11200
6300 IF SYSNO%=SYS% THEN 6330
6310 IC=IC+1
6320 GOTO 6270
6330 IRECNO=IC
6340 GOSUB 8100
6350 GOSUB 6600
6500 IC=IC+1
6510 GOTO 6270
6520 RETURN
6530 PRINT "ERROR - DYE SYSTEM NOT FOUND"
6540 INPUT "HIT 'RETURN' TO CONTINUE", ANY$
6550 RETURN
6560 END
```

```
6600 REM  CHANGE DYESTUFF O.W.F.
6610 LOCATE 22,1,1
6620 PRINT "TYPE NEW DYESTUFF o.w.f. AND 'RETURN' FOR EACH LINE"
6630 PRINT "OR HIT 'RETURN' ONLY FOR NO CHANGE"
6640 FOR I=1 TO 4
6650 IF DYE$(I)="     " THEN 6700
6660 LOCATE (2+I),32,1
6670 INPUT CHANGES$
6680 IF CHANGES$="" THEN 6700
6690 DOWF(I)=VAL(CHANGES$)
6700 NEXT I
6710 GOSUB 8100
6720 LOCATE 23,1,1
6730 INPUT "CORRECT <Y or N> ";Q$
6740 IF Q$="Y" OR Q$="y" THEN 6760
6745 GOSUB 8100
6750 GOTO 6610
6760 GOSUB 7300
6770 RETURN
6775 END
```

```
6800 REM  GET  STYLE AND SHADE
6810 CLS
6820 PRINT "INPUT STYLE AND SHADE"
6830 PRINT
6840 FOR I=1 TO 10
6850 PRINT I;"   ";STYLE$(I)
6860 NEXT I
6870 PRINT
6880 INPUT "TYPE NUMBER OF STYLE  ",STYLENO%
6890 IF STYLENO%<1 OR STYLENO%>10, THEN PRINT "INVALID ENTRY": GOTO 6870
6900 PRINT
6910 PRINT
6920 INPUT "INPUT SHADE NUMBER  ",SHADE
6930 IF SHADE<1, THEN PRINT "INVALID ENTRY": GOTO 6910
6940 PRINT
6950 PRINT
6960 PRINT STYLE$(STYLENO%);"  SHADE";SHADE
6970 PRINT "Correct <Y or N>";
6980 INPUT Q$
6990 IF Q$ = "Y" OR Q$ = "y", THEN RETURN
7000 GOTO 6810
7010 END
```

```
7100 REM  READ FILE UNTIL CORRECT RECIPE FOUND
7110 I=1
7120 GET #1,I
7130 IF EOF(1) THEN 7240
7140 STY%=CVI(A$)
7145 IF STY%=0 THEN 7240
7150 IF STY%=STYLENO% THEN 7180
7160 I=I+1
7170 GOTO 7120
7180 SHD=CVS(B$)
7190 IF ABS(SHD-SHADE)<.001 THEN 7220
7200 I=I+1
7210 GOTO 7120
7220 IRECNO=I
7230 RETURN
7240 ILASTREC=I
7250 RETURN
7260 END
```

```
7300 REM  OUTPUT RECIPE RECORD
7310 LSET A$=MKI$(STYLENO%)
7320 LSET B$=MKS$(SHADE)
7330 LSET C$=MKI$(SYSNO%)
7340 LSET E$=MKS$(DOWF(1))
7350 LSET G$=MKS$(DOWF(2))
7360 LSET I$=MKS$(DOWF(3))
7370 LSET K$=MKS$(DOWF(4))
7380 PUT #1,IRECNO
7390 RETURN
7400 END
```

```
7500 REM  OUTPUT SYSTEM RECORD
7510 LSET CC$=MKI$(SYS%)
7520 LSET X3$=MKI$(STYLENO%)
7530 LSET NN$=MKI$(N)
7540 LSET A1$=MKI$(GAMMA(1))
7550 LSET B1$=MKI$(GAMMA(2))
7560 LSET C1$=MKI$(GAMMA(3))
7570 LSET D1$=MKI$(GAMMA(4))
7580 LSET A2$=MKS$(K(1,1))
7590 LSET B2$=MKS$(K(1,2))
7600 LSET C2$=MKS$(K(1,3))
7610 LSET D2$=MKS$(K(1,4))
7620 LSET E2$=MKS$(K(2,1))
7630 LSET F2$=MKS$(K(2,2))
7640 LSET G2$=MKS$(K(2,3))
7650 LSET H2$=MKS$(K(2,4))
7660 LSET I2$=MKS$(K(3,1))
7670 LSET J2$=MKS$(K(3,2))
7680 LSET K2$=MKS$(K(3,3))
7690 LSET L2$=MKS$(K(3,4))
7700 LSET M2$=MKS$(K(4,1))
7710 LSET N2$=MKS$(K(4,2))
7720 LSET O2$=MKS$(K(4,3))
7730 LSET P2$=MKS$(K(4,4))
7740 LSET O$=MKS$(AOWF(1))
7750 LSET R$=MKS$(AOWF(2))
7760 LSET T$=MKS$(AOWF(3))
7770 LSET V$=MKS$(AOWF(4))
7780 LSET X$=MKS$(AOWF(5))
7790 LSET Z$=MKS$(AOWF(6))
7800 LSET BB$=MKS$(AOWF(7))
7810 LSET N$=MKS$(ACON(1))
```

```
7820 LSET P$=MKS$(ACON(2))
7830 LSET S$=MKS$(ACON(3))
7840 LSET U$=MKS$(ACON(4))
7850 LSET W$=MKS$(ACON(5))
7860 LSET Y$=MKS$(ACON(6))
7870 LSET AA$=MKS$(ACON(7))
7880 LSET A3$=DYE$(1)
7890 LSET B3$=DYE$(2)
7900 LSET C3$=DYE$(3)
7910 LSET D3$=DYE$(4)
7920 LSET E3$=AUX$(1)
7930 LSET F3$=AUX$(2)
7940 LSET G3$=AUX$(3)
7950 LSET H3$=AUX$(4)
7960 LSET I3$=AUX$(5)
7970 LSET J3$=AUX$(6)
7980 LSET K3$=AUX$(7)
7990 PUT #2,SYS%
8000 RETURN
8010 END
```

```
8100 REM  PRINT RECIPE
8110 CLS
8120 PRINT "STYLE: "; STYLE$(STYLENO%);"    SHADE: ";SHADE
8130 PRINT
8140 FOR I=1 TO 4
8150 IF DYE$(I)="     ", THEN PRINT: GOTO 8190
8160 PRINT DYE$(I) TAB(16);
8170 PRINT USING "##.####"; DOWF(I);
8180 PRINT " % o.w.f."
8190 NEXT I
8200 FOR I=1 TO 7
8210 IF AUX$(I)="       ", THEN PRINT: GOTO 8250
8220 PRINT AUX$(I) TAB(16);
8230 PRINT USING "##.##"; AOWF(I);
8240 PRINT " % o.w.f."
8250 NEXT I
8260 RETURN
8270 END
```

```
8300 REM  REVIEW DYE SYSTEMS
8310 CLS
8320 PRINT "PLEASE REVIEW THE FOLLOWING DYE SYSTEMS AND SELECT THE CORRECT ONE"
8330 PRINT
8340 INPUT "HIT 'RETURN' TO CONTINUE",ANY$
8350 ID=1
8360 GET #2,ID
8370 IF EOF(2) THEN 8560
8380 SYSTY%=CVI(X3$)
8385 IF SYSTY%=0 THEN 8560
8390 IF SYSTY%=STYLENO% THEN 8420
8400 ID=ID+1
8410 GOTO 8360
8420 GOSUB 11300
8430 GOSUB 11700
8440 GOSUB 10600
8450 PRINT: PRINT
8460 INPUT "ARE THESE THE CORRECT DYESTUFFS AND K-VALUES <Y or N> ";Q$
8470 IF Q$="Y" OR Q$="y" THEN 8500
8480 ID=ID+1
8490 GOTO 8360
8500 GOSUB 10500
8510 PRINT: PRINT
8520 INPUT "ARE THESE THE CORRECT AUXILIARY CHEMICALS AND % o.w.f. <Y or N> ";Q$
8530 IF Q$="Y" OR Q$="y" THEN 8570
8540 ID=ID+1
8550 GOTO 8360
8560 LASTREC=ID: GOSUB 8600
8570 SYSNO%=SYS%
8580 RETURN
8590 END
```

```
8600 REM  ADD NEW DYE SYSTEM
8610 CLS
8620 PRINT "MUST ADD NEW DYE SYSTEM"
8630 PRINT
8640 INPUT "INPUT NUMBER OF DYES <1 to 4>";N
8650 IF N<1 OR N>4 THEN PRINT "INVALID ENTRY": PRINT: GOTO 8640
8660 FOR I=1 TO 4
8670 IF I>N THEN DYE$(I)="     ": GAMMA(I)=0: GOTO 8750
8680 PRINT: PRINT "DYESTUFF NAME #";I;
8690 INPUT DYE$(I)
8700 IF LEN(DYE$(I))>5 THEN DYE$(I)=LEFT$(DYE$(I),5): GOTO 8720
8710 IF LEN(DYE$(I))<5 THEN DYE$(I)=DYE$(I)+STRING$((5-LEN(DYE$(I)))," ")
8720 PRINT DYE$(I);
8730 INPUT " CORRECT <Y or N>";Q$
8740 IF Q$="Y" OR Q$="y" THEN 8750 ELSE GOTO 8680
8750 NEXT I
8760 PRINT: PRINT
8770 FOR I=1 TO N
8780 PRINT: PRINT "GAMMA #";I;
8790 INPUT GAMMA(I)
8800 PRINT GAMMA(I);"nm";
8810 INPUT " CORRECT <Y or N>";Q$
8820 IF Q$="Y" OR Q$="y" THEN 8830 ELSE GOTO 8780
8830 NEXT I
8840 FOR I=1 TO 4
8850 FOR J=1 TO 4
8860 K(I,J)=0!
8870 NEXT J
8880 NEXT I
8890 GOSUB 10600
8900 PRINT: PRINT: PRINT "INPUT K-VALUES"
8910 FOR I=1 TO N
8920 FOR J=1 TO N
8930 LOCATE (2+I),(8*J+15),1
8940 INPUT "",K(J,I)
8950 NEXT J
8960 LOCATE (2+I),1,1: PRINT STRING$(80," "): LOCATE (2+I),1,1
8970 PRINT TAB(2);DYE$(I);TAB(20);
8980 PRINT USING "#####.##";K(1,I);K(2,I);K(3,I);K(4,I);
8990 INPUT " CORRECT <Y or N>";Q$
9000 IF Q$="Y" OR Q$="y" THEN 9010 ELSE GOTO 8920
9010 NEXT I
9020 CLS
9030 INPUT "TYPE NUMBER OF AUXILIARY CHEMICALS <0 to 7> ";NUM
```

```
9040 IF NUM<0 OR NUM>7 THEN PRINT "INVALID ENTRY": PRINT: GOTO 9030
9050 FOR I=1 TO 7
9060 IF I > NUM, THEN AUX$(I)="        ": ACON(I)=0!: GOTO 9230
9070 PRINT: PRINT
9080 PRINT "AUXILIARY #";I;
9090 INPUT AUX$(I)
9100 IF LEN(AUX$(I))>8 THEN AUX$(I)=LEFT$(AUX$(I),8): GOTO 9120
9110 IF LEN(AUX$(I))<8 THEN AUX$(I)=AUX$(I)+STRING$(8-LEN(AUX$(I))," ")
9120 INPUT "UNITS <1 for POUNDS, 2 for GALLONS>";UNITS
9130 IF UNITS=1 THEN UNIT$(I)="lbs": ACON(I)=0!: GOTO 9170
9140 IF UNITS=2 THEN UNIT$(I)="gal": GOTO 9160
9150 GOTO 9120
9160 INPUT "UNIT WEIGHT (lb/gal)";ACON(I)
9170 PRINT: PRINT "NAME","UNITS","lb/gal"
9180 PRINT AUX$(I), UNIT$(I),
9190 IF UNIT$(I)="gal" THEN PRINT ACON(I);
9200 PRINT TAB(42);
9210 INPUT " CORRECT <Y or N>";Q$
9220 IF Q$="Y" OR Q$="y" THEN 9230 ELSE 9070
9230 NEXT I
9240 FOR I=1 TO 7
9250 AOWF(I)=0!
9260 NEXT I
9270 GOSUB 10500
9280 PRINT: PRINT: PRINT "INPUT % o.w.f."
9290 FOR I=1 TO 7
9300 IF AUX$(I)="        " THEN 9330
9310 LOCATE (2+I),30,1
9320 INPUT "",AOWF(I)
9330 NEXT I
9340 GOSUB 10500
9350 PRINT: PRINT: INPUT "CORRECT <Y or N> ";Q$
9360 IF Q$="Y" OR Q$="y" THEN 9380
9370 GOTO 9270
9380 SYS%=LASTREC
9390 GOSUB 7500
9400 RETURN
9410 END
```

```
9500 REM  EDIT SYSTEM
9510 PRINT "YOU HAVE INDICATED THAT THE NAMES OF DYES AND/OR AUXILIARY"
9520 PRINT "CHEMICALS USED TO DYE THIS SHADE HAVE CHANGED."
9530 PRINT
9540 PRINT "WILL *ALL* SHADES IN THIS STYLE FORMERLY DYED WITH THESE DYES AND"
9550 INPUT "AUXILIARIES ALSO HAVE THE SAME CHANGES <Y or N> ";Q$
9560 IF Q$="N" OR Q$="n" THEN 8300
9570 GOSUB 10600
9580 GFLAG=0
9590 LOCATE 18,1,1
9600 INPUT "DO WAVELENGTHS CHANGE ";Q$
9610 IF Q$="N" OR Q$="n" THEN 9710
9620 PRINT: PRINT "TYPE IN NEW WAVELENGTH AND 'RETURN' TO MAKE CHANGE"
9630 PRINT "OR, FOR NO CHANGE, JUST HIT 'RETURN'"
9640 GFLAG=1
9650 FOR I=1 TO N
9660 LOCATE 1,(9*I+15),1
9670 INPUT "",CHANGES$
9680 IF CHANGES$="" THEN 9700
9690 GAMMA(I)=VAL(CHANGES$)
9700 NEXT I
9710 LOCATE 18,1,1
9720 INPUT "DO DYESTUFF NAMES CHANGE ";Q$
9730 IF Q$="N" OR Q$="n" AND GFLAG<.5, THEN 9900
9740 PRINT: PRINT "TYPE IN NEW DYE NAMES AND K-VALUES AND 'RETURN' AFTER EACH"
9750 PRINT "OR, FOR NO CHANGE, JUST HIT 'RETURN'"
9760 FOR I=1 TO N
9770 LOCATE (2+I),2,1
9780 INPUT "",CHANGES$
9790 IF CHANGES$="" THEN 9820
9800 IF LEN(CHANGES$) >=5 THEN DYE$(I)=LEFT$(CHANGES$,5): GOTO 9830
9810 DYE$(I)=CHANGES$ + STRING$(5-LEN(CHANGES$)," ")
9820 IF GFLAG<.5 THEN 9890
9830 FOR J=1 TO N
9840 LOCATE (2+I),(8*J+14),1
9850 INPUT "",CHANGES$
9860 IF CHANGES$="" THEN 9880
9870 K(J,I)=VAL(CHANGES$)
9880 NEXT J
9890 NEXT I
9900 GOSUB 10600
9910 LOCATE 23,1,1
9920 INPUT "CORRECT <Y or N> ";Q$
9930 IF Q$="Y" OR Q$="y" THEN 9950
9940 GOTO 9570
9950 CLS: INPUT "DO AUXILIARY NAMES OR UNITS CHANGE <Y or N> ";Q$
9960 IF Q$="N" OR Q$="n" THEN 10240
9970 GOSUB 10700
9980 FOR I=1 TO 7
9990 LOCATE 21,1,1
10000 PRINT "TYPE IN NEW AUXILIARY NAME AND HIT 'RETURN' TO MAKE CHANGE"
```

```
10010 PRINT "OR, FOR NO CHANGE, HIT 'RETURN' ONLY"
10020 PRINT "OR, TO DELETE, TYPE 'D'"
10030 LOCATE (2+I),2,1
10040 INPUT "",CHANGES$
10050 IF CHANGES$="D" OR CHANGES$="d" THEN AUX$(I)="        ": UNIT$(I)="   ": ACON(I)=0!: AOWF(I)=0!
: GOTO 10230
10060 IF CHANGES$="" THEN 10090
10070 IF LEN(CHANGES$) >= 8 THEN AUX$(I)=LEFT$(CHANGES$,8): GOTO 10090
10080 AUX$(I)=CHANGES$ + STRING$(8-LEN(CHANGES$)," ")
10090 IF AUX$(I)="        " THEN 10230
10100 LOCATE 21,1,1
10110 PRINT "TYPE AUXILIARY UNITS: 'GAL' FOR GALLONS OR 'LBS' FOR POUNDS"
10120 LOCATE (2+I),21,1
10130 INPUT "",CHANGES$
10140 IF CHANGES$="" THEN 10160
10150 UNIT$(I)=CHANGES$
10160 IF LEFT$(UNIT$(I),1)="l" OR LEFT$(UNIT$(I),1)="L" THEN ACON(I)=0: GOTO 10230
10170 LOCATE 21,1,1: PRINT STRING$(80," "): LOCATE 21,1,1
10180 PRINT "TYPE UNIT WEIGHT (lb/gal)"
10190 LOCATE (2+I),32,1
10200 INPUT "",CHANGES$
10210 IF CHANGES$="" THEN 10230
10220 ACON(I)=VAL(CHANGES$)
10230 NEXT I
10240 GOSUB 10700
10250 LOCATE 23,1,1
10260 INPUT "CORRECT <Y or N> ";Q$
10270 IF Q$="Y" OR Q$="y" THEN 10290
10280 GOTO 9970
10290 INPUT "DO AUXILIARY CHEMICAL % o.w.f. VALUES CHANGE <Y or N> ";Q$
10300 IF Q$="N" OR Q$="n" THEN 10430
10310 REM  ENTRY POINT FOR AUXILIARY OWF CHANGES
10320 GOSUB 10500
10330 LOCATE 22,1,1
10340 PRINT "TYPE NEW % o.w.f. AND HIT 'RETURN' TO MAKE CHANGE"
10350 PRINT "OR, FOR NO CHANGE, HIT 'RETURN' ONLY"
10360 FOR I=1 TO 7
10370 IF AUX$(I)="        " THEN 10420
10380 LOCATE (2+I),30,1
10390 INPUT "",CHANGES$
10400 IF CHANGES$="" THEN 10420
10410 AOWF(I)=VAL(CHANGES$)
10420 NEXT I
10430 GOSUB 10500
10440 LOCATE 23,1,1
10450 INPUT "CORRECT <Y or N> ";Q$
10460 IF Q$="Y" OR Q$="y" THEN 10480
10470 GOTO 10320
10480 GOSUB 7500
10490 RETURN
10495 END
```

```
10500 REM  LIST AUXILIARY OWF
10510 CLS: PRINT "AUXILIARY","UNITS","% o.w.f.": PRINT
10520 FOR I=1 TO 7
10530 IF AUX$(I)="        " THEN 10550
10540 PRINT AUX$(I),UNIT$(I),: PRINT USING "##.##"; AOWF(I)
10550 NEXT I
10560 RETURN
10570 END
```

```
10600 REM  LIST DYES
10610 CLS
10620 PRINT TAB(1) "WAVELENGTH (nm)" TAB(23) GAMMA(1) TAB(32) GAMMA(2) TAB(41);
10630 PRINT GAMMA(3) TAB(50) GAMMA(4)
10640 PRINT
10650 FOR I=1 TO N
10660 PRINT TAB(2) DYE$(I) TAB(20);
10670 PRINT USING "#####.##"; K(1,I),K(2,I),K(3,I),K(4,I)
10680 NEXT I
10690 RETURN
10695 END
```

```
10700 REM  LIST AUXILIARIES
10710 CLS
10720 PRINT "AUXILIARY" TAB(20) "UNITS" TAB(30) "WT (gal/lb)": PRINT
10730 FOR I=1 TO 7
10740 IF AUX$(I)="        " THEN 10780
10750 PRINT TAB(2) AUX$(I) TAB(21) UNIT$(I) TAB(31);
10760 IF ACON(I)>.01, THEN PRINT ACON(I);
10770 PRINT " "
10780 NEXT I
10790 RETURN
10795 END
```

```
10800 REM  LIST ALL RECIPES
10810 CLS
10820 PRINT "WHERE DO YOU WANT THE RECIPES LISTED?"
10830 INPUT "TYPE '1' FOR SCREEN OR '2' FOR PRINTER ",OUTLIST%
10840 CLS
10850 I=1
10860 GET #2,I
10870 IF EOF(2) THEN 11090
10880 GOSUB 11300
10890 IF OUTLIST%=2 THEN LPRINT:LPRINT:LPRINT ELSE PRINT:PRINT:PRINT
10900 IF OUTLIST%=2 THEN LPRINT "STYLE" SPC(5) "SHADE  "; ELSE PRINT "STYLE" SPC(5) "SHADE  ";
10910 IF OUTLIST%=2 THEN LPRINT USING "\     \";DYE$(1);DYE$(2);DYE$(3);DYE$(4);
      ELSE PRINT USING "\     \";DYE$(1);DYE$(2);DYE$(3);DYE$(4);
10920 IF OUTLIST%=2 THEN LPRINT USING "\   \";AUX$(1);AUX$(2);AUX$(3);AUX$(4);AUX$(5);AUX$(6);AUX$(7)
      ELSE PRINT USING "\   \";AUX$(1);AUX$(2);AUX$(3);AUX$(4);AUX$(5);AUX$(6);AUX$(7)
10930 IF OUTLIST%=2 THEN LPRINT ELSE PRINT
10940 J=1
10950 GET #1,J
10960 IF EOF(1) THEN 11070
10970 SYSNO%=CVI(C$)
10980 IF SYSNO%<>SYS% THEN 11050
10990 STY%=CVI(A$)
11000 SHD=CVS(B$)
11010 GOSUB 11200
11020 IF OUTLIST%=2 THEN LPRINT LEFT$(STYLE$(STY%),8) TAB(10) SHD; ELSE PRINT LEFT$(STYLE$(STY%),8)
      TAB(10) SHD;
11030 IF OUTLIST%=2 THEN LPRINT USING "##.####"; DOWF(1);DOWF(2);DOWF(3);DOWF(4); ELSE PRINT USING
      "##.####"; DOWF(1);DOWF(2);DOWF(3);DOWF(4);
11040 IF OUTLIST%=2 THEN LPRINT USING "##.##";AOWF(1);AOWF(2);AOWF(3);AOWF(4);AOWF(5);AOWF(6);
      AOWF(7) ELSE PRINT USING "##.##"; AOWF(1);AOWF(2);AOWF(3);AOWF(4);AOWF(5);AOWF(6);AOWF(7)
11050 J=J+1
11060 GOTO 10950
11070 I=I+1
11080 GOTO 10860
11090 INPUT "HIT 'RETURN' TO CONTINUE",ANY$
11100 RETURN
11110 END
```

```
11200 REM  CONVERT RECIPE RECORD
11210 DOWF(1)=CVS(E$)
11220 DOWF(2)=CVS(G$)
11230 DOWF(3)=CVS(I$)
11240 DOWF(4)=CVS(K$)
11250 SYSNO%=CVI(C$)
11260 RETURN
11270 END
```

```
11300 REM  CONVERT SYSTEM RECORD - PART 1
11310 AOWF(1)=CVS(O$)
11320 AOWF(2)=CVS(R$)
11330 AOWF(3)=CVS(T$)
11340 AOWF(4)=CVS(V$)
11350 AOWF(5)=CVS(X$)
11360 AOWF(6)=CVS(Z$)
11370 AOWF(7)=CVS(BB$)
11380 SYS%=CVI(CC$)
11390 SYSTY%=CVI(X3$)
11400 N=CVI(NN$)
11410 ACON(1)=CVS(N$)
11420 ACON(2)=CVS(P$)
11430 ACON(3)=CVS(S$)
11440 ACON(4)=CVS(U$)
11450 ACON(5)=CVS(W$)
11460 ACON(6)=CVS(Y$)
11470 ACON(7)=CVS(AA$)
11480 FOR IC=1 TO 7
11490 IF ACON(IC)>.01, THEN UNIT$(IC)="gal": GOTO 11510
11500 UNIT$(IC)="lbs"
11510 NEXT IC
11520 DYE$(1)=A3$
11530 DYE$(2)=B3$
11540 DYE$(3)=C3$
11550 DYE$(4)=D3$
11560 AUX$(1)=E3$
11570 AUX$(2)=F3$
11580 AUX$(3)=G3$
11590 AUX$(4)=H3$
11600 AUX$(5)=I3$
11610 AUX$(6)=J3$
11620 AUX$(7)=K3$
11630 RETURN
11640 END
```

```
11700 REM  CONVERT SYSTEM RECORD - PART 2
11710 GAMMA(1) = CVI(A1$)
11720 GAMMA(2) = CVI(B1$)
11730 GAMMA(3) = CVI(C1$)
11740 GAMMA(4) = CVI(D1$)
11750 K(1,1) = CVS(A2$)
11760 K(1,2) = CVS(B2$)
11770 K(1,3) = CVS(C2$)
11780 K(1,4) = CVS(D2$)
11790 K(2,1) = CVS(E2$)
11800 K(2,2) = CVS(F2$)
11810 K(2,3) = CVS(G2$)
11820 K(2,4) = CVS(H2$)
11830 K(3,1) = CVS(I2$)
11840 K(3,2) = CVS(J2$)
11850 K(3,3) = CVS(K2$)
11860 K(3,4) = CVS(L2$)
11870 K(4,1) = CVS(M2$)
11880 K(4,2) = CVS(N2$)
11890 K(4,3) = CVS(O2$)
11900 K(4,4) = CVS(P2$)
11910 RETURN
11920 END
```

```
12000 REM  END
12010 CLOSE
12020 SYSTEM
12030 PRINT "RUN ERROR - PROGRAM ABORT - FILES SAVED"
12040 CLOSE
12050 SYSTEM
```

APPENDIX G

ADDITIONAL INFORMATION SOURCES

You may be interested in some of the research and development that has already been undertaken for dyebath reuse. Appendix G1 provides a list and background of the principal researchers in the field. Appendix G2 presents a tabulation of a literature review conducted in 1983, with a breakdown by product type. Appendix G3 presents the actual references and bibliography for Appendix G2, and also applies to the overall development of Phase III work.

G1 - PRINCIPAL RESEARCHERS

Georgia Institute of Technology
School of Textile Engineering
Atlanta, Georgia 30332
404-894-2490

Georgia Tech has been conducting research on dyebath reuse since about 1975. Their work has ranged from laboratory and pilot scale experiments to full scale in-plant demonstrations in various sectors of the textile industry. Much of the research has been published in the industry journals and in Department of Energy publications, as listed in Appendix D3. The following are the principal investigators:

Dr. Wayne C. Tincher - Professor
Dr. Fred L. Cook - Associate Professor
Dr. Wallace W. Carr - Associate Professor

Sverdrup & Parcel and Associates, Inc. (S&P)
801 North Eleventh
St. Louis, Missouri 63101
314-436-7600

S&P conducted a research project on behalf of the U.S. EPA (Contract 68-02-3678) for recycle and reuse of textile wastewater streams, of which this Phase III report is a part. Activities on dyebath reuse included literature review, laboratory and pilot scale experiments, development of computer programs for dyebath analysis, inplant demonstration, environmental sampling and analysis, and report preparation. The principal investigators are the following:

Robert Hendriks - EPA Project Officer
Jon Bergenthal - Project Manager
Anthony Tawa - Project Engineer
Steve Schaefer - Project Engineer

G2 - LITERATURE REVIEW

The results of an extensive literature review are summarized in the following table. The fabric or product type is the main identifier, followed by a description of the results of the research. The references are listed in Appendix G3.

SUMMARY OF LITERATURE REVIEW

Fabric/Product	Dyes/Aux/Dye Machinery	Scale	Comments/Problems	Ref.
Nylon Carpet	Acid Open Beck Ammonia aids leveling. Keeps pH on basic side. Must extract dyes with octanol to remove tints normally removed in prescour.	Full	"Bump & Run" Temp. Control Dyebath Reuse "Hot Pull" of Dyed Carpet Must replace volatized ammonia for leveling.	1
Nylon Carpet	Acid or Disperse Open Beck	Pilot	Tried ammonium hydroxide to retard rapid strike, but appeared that it was unnecessary. Got level dyeings at the boil. Need retarder to control dye strike at high temperature. Levelers affect exhaustion rate of different dyes differently. Dispersing agent is surfactant that competes for exhaustion.	2, 3, 4, 5, 6, 7, 8
Polyester Carpet	Disperse Open Beck	Pilot	Use biphenyl carrier that exhausts on fabric partially; also gets discharged and may be aesthetically unpleasant.	9, 8, 7, 4, 5
Nylon Carpet	Acid Open Beck	Full	Some problems with leveler/retarder temperature. Not resolved yet.	Personal communication (identity confidential)
Nylon Pantyhose	Disperse Overhead Paddle or Rotating Drum Machines	Full	Excellent technically, over 40 dyeings from one bath. Frequent analysis, 1 shift/day operation, low volume/batch. Hurt economics slightly.	10, 11

SUMMARY OF LITERATURE REVIEW (Continued)

Fabric/Product	Dyes/Aux/Dye Machinery	Scale	Comments/Problems	Ref.
Nylon Pantyhose Nylon 66 or 6	Disperse Generally only about 3 shades Auxiliaries vary very little	Pilot	High exhaustion of dyes (90-97%) Short dye cycles Low volume loads More frequent analysis	8, 5, 4
Polyester Yarn Packages (Spun & Textured Yarns)	Disperse, Pressure Jets & Becks Jet more efficient	Pilot	Growing area, pressure used to avoid use of biphenyl carrier. Achieved reuse of $NaOH/NaHSO_3$ reduction and clearing baths	12, 8, 5, 4
			Dye reuse successful on single shade and selected multishade sequences. Light to dark sequence needed with dye overlap. Add package before dye to avoid initial hard strike. Green to yellow failed. Green to grey okay.	
Cotton and Cotton/Polyester Woven Fabrics	Reactive Reactive/Disperse Reactives expensive ($5-$20/lb) Vat & Direct dyes expected to be curtailed, Vat for Hg pollution, direct for Carcinogens (Benzidine metabolized in body)	Pilot	Requires split bath technique to prevent reactive dye hydrolyses. Reactives often less than 80% exhaustion. Lots of auxiliaries used. Dye is hydrolyzed by base. Fixation causes step up in exhaustion in split bath, since impregnation bath is removed. Higher dye amounts are necessary initially. Hydrolyzed dye added to fixation bath to prevent bleed off. Store reactive dye at pH 6.0 to avoid hydrolysis. Must use 2 dye types in one bath to decrease number of cycles. Need base-stable disperse with high temperature reactive. GA Tech has developed programs to determine amount of excess dye needed due to lack of step-up, as in conventional method.	13, 8, 5

SUMMARY OF LITERATURE REVIEW (Continued)

Fabric/Product	Dyes/Aux/Dye Machinery	Scale	Comments/Problems	Ref.
Nylon Socks	Acid	Pilot	Low volume loads Short dye cycles More frequent analysis Technically okay	8
Acrylic Socks	Acid/Basic	Pilot	Needs process modification, such as split bath technique	8
Nylon Upholstery Fabric w/Cotton Backing	Acid/Direct	Pilot	Needs further work; process modification. Difficulty with Erional NW (CIBA - GEIGY). Hinders dye solubility, interferes with another auxiliary called Weslevel NL (Retarder/Leveler). Severe analysis difficulties. Tough to analyze Lanasyn Red 2GL.	8
Nomex Type 455 Woven Fabric	Cationic-Jet Dyeing includes a unique carrier that exhausts on fabric	Pilot & Full	Need 1 Octanol to extract dye from dyebath. Must analyze dye carrier by nuclear magnetic resonance spectroscopy for 2 components that exhaust differently on fabric. Average exhaustion was 65%. Test dyeings were successful.	14
Acrylic Yarns	Basic	Full	Use known exhaust rate.	15
Cotton Woven Fabric	Direct	Full	Use known exhaust rate.	Personal communication (identity confidential)
Heavy Black Shades Cellulosic Fibers	Sulfur	Common Practice	Replenished dyes by experience	17 p. 491 as cited in 13, p. 10

SUMMARY OF LITERATURE REVIEW (Continued)

Fabric/Product	Dyes/Aux/Dye Machinery	Scale	Comments/Problems	Ref.
CONSTANT TEMPERATURE DYEING TECHNIQUES				
Acrylic Goods	Cationic		Proper selection of dye concentration and assistants is very important.	13 p. 10-11 (Citing early research efforts. Citations also noted as 13a 13b, 13c, 13d, 13e, and 13f)
Nylon Goods	Anionic			

G3 - REFERENCES/BIBLOGRAPHY

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3. Tata, A. S., "Technical Feasibility of Dyeing Nylon Carpets in a Reconstituted Dyebath," Master's Thesis, George Institute of Technology, 1976.

4. Cook, F. L. and W. C. Tincher. "Dyebath Reuse in Batch Dyeing," Textile Chemist and Colorist, Vol. 10, No. 1 (January 1978), pp. 21-25.

5. Cook, F. L. and W. C. Tincher. "Dyebath and Auxiliary Bath Reuse for Energy and Mass Conservation," Energy Conservation in Textile and Polymer Processing, American Chemical Society Symposium Series 107, 1979, pp. 201-241.

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